Exponent®

Report of Dr. Brenton Cox Regarding the May 31, 2017 Explosion at Didion Milling in Cambria, Wisconsin

Exponent

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Table 1. Glossary of some terms employed in the grain milling industry 4

Acronyms and Abbreviations

CG	Coarse Grinder
CSB	U.S. Chemical Safety Board
MEC	Minimum Explosible Concentration
MOC	Management of Change
NBM	North Bauermeister
NCS	Non-structural Carbohydrates
PCM	Pregelatinized Corn Meal
PFD	Process Flow Diagram
PPS	Product Protection System
RCPF	Raw Corn Processing Facility
SBM	South Bauermeister
TDF	Total Dietary Fiber

Limitations

The scope of services performed during this investigation may not adequately address the needs of other users of this report, and any re-use of this report or its findings, conclusions, or recommendations presented herein is at the sole risk of the user. Specifically, this report was prepared at the request of Didion Milling's counsel in the matter currently pending in the U.S. District Court for the Western District of Wisconsin (Case No. 3:22-cr-00055-jdp) and is focused on the issues relevant to that matter. This report is not intended, directly or indirectly, to apply to or cover all issues that may be relevant in other litigation or disputes related to the subject incident, including but not limited to other civil litigation or governmental investigations. The opinions and comments formulated during this assessment are based on observations and information available at the time of the investigation.

The findings presented herein are made to a reasonable degree of scientific and engineering certainty. Exponent has made every effort to accurately and completely investigate all areas of concern identified during our investigation. If new data become available or there are perceived omissions or misstatements in this report regarding any aspect of those conditions, I ask that they be brought to our attention as soon as possible so that we have the opportunity to fully address them.

1 Executive Summary

As a result of my investigation, I have developed several opinions.[1] I hold the following opinions to a reasonable degree of engineering and scientific certainty based on relevant literature and standards, common practices in the industry, and the materials that I have reviewed to date. I reserve the right to supplement this report and to expand or modify any opinions based on review of material as it becomes available through ongoing discovery and through any additional work.

Opinion 1: The explosion originated in the South Bauermeister (SBM) on the first floor of the B-Mill (B1). The explosion was preceded by an upset in the operation of the SBM.[2]

Opinion 2: Multiple explosions (deflagrations) occurred within the Bran System, starting before the departure of witnesses from B1, as indicated by the flames described as extending from the air inlet duct that serves the discharge line of the SBM. Explosions propagated internally within process equipment and dust collection equipment located in B1 to equipment located throughout the facility, contributing to the magnitude and distribution of the damage and destruction observed after the incident.

Opinion 3: As a result of the internal propagation of explosions through ducts and equipment, material was ejected at high velocity and concentration from multiple process and dust collection sources during the incident, including from equipment, separated ducts, and flanges. These ejections created explosive mixtures in air, several of which ignited. An explosion within the room B1 followed the initial internal explosions within the Bran System. In-process material ejected during the event provided adequate fuel to explain the damage observed in B1.

Opinion 4: The explosion in B1 was shortly followed by an explosion in the Dry Grit Filter. The explosion occurred due to internal propagation through process and dust collection equipment, and the most direct propagation pathway was through the Government Line lift gate located underneath the damaged fan downstream of the SBM. The propagation of the explosion through the Dry Grit Filter header provided pathways to equipment in both the Pack area and the Product Protection System (PPS) area. Propagation of the explosion into the Pack and PPS areas via this header may have contributed to the damage in these areas.

Opinion 5: Fires and explosions fueled by other material also occurred throughout the facility. For example, a cylinder containing liquefied petroleum gas (LP-gas) exploded within the Pack area, contributing to the damage in this portion of the mill. A transformer was also damaged due to a concrete wall panel that fell from the B-Mill, resulting in a fire and/or explosion fueled by transformer oil.

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1 Note that this Executive Summary does not contain all of Exponent's technical evaluations, analyses, conclusions, and recommendations. Hence, the main body of this report is at all times the controlling document.

2 The exact ignition event is not at issue in this criminal matter, and therefore it is not analyzed or addressed in detail. To the extent the exact ignition event (and cause thereof) is an issue in other disputes or litigation related to the subject incident, Exponent reserves its right to analyze, develop, and/or clarify its opinions in the future.

Rebuttal Opinions

Opinion 6: Mr. Cholin's determination regarding the cause of propagation of the explosion throughout the facility is erroneous. Mr. Cholin's report stated that, "All of the evidence we have been able to study supports the conclusion that all of the injuries were either the direct consequence of the deflagration fueled by accumulated dust or the consequence of structural failure caused by those dust deflagrations."[3] However, Mr. Cholin's analysis is based on circular reasoning that lacks substantiation. In summary, he concludes that accumulated dust must have been present and must have been the cause of the event because he otherwise lacks the ability to explain it. However, internal propagation of interconnected equipment is a known phenomenon and the in-process material was a viable fuel. The evidence shows that material originating inside equipment/ducts and material ejected from equipment/ducts were the primary sources of fuel during the incident, with respect to both the primary and the subsequent explosions. In fact, deflagrations must have propagated internally before any external explosions were observed because their ignition occurred internal to equipment. Additionally, the only viable explanation for the Dry Grit Filter explosion observed shortly after the B1 explosion is due to internal propagation. Yet Mr. Cholin failed to consider the role of internal propagation. Thus, his conclusions regarding the role of fugitive dust in this event are not substantiated.

Opinion 7: Mr. Cholin's analysis of "alternative scenarios identified by others as possible causes"[4] fails to prove or disprove anything about the propagation of the explosion throughout the facility. Instead, these hypotheses are constructed as strawman arguments addressed with perfunctory and selectively applied analyses that fail to disprove that any of the underlying mechanisms were key factors in the complex, dynamic event. The evidence shows that key mechanisms that Mr. Cholin ignored, dismissed, and/or erroneously analyzed contributed to this complex event.

Opinion 8: Mr. Osborn's opinions regarding the performance of Didion's dust collection systems allege that combustible dust would be present at all times within the Torit and Dry Grit Filter dust collection headers. Indeed, even in the best performing dust collection system, there will inevitably be dust (fuel) present in the dust collection system during operation. Thus, his opinions are irrelevant to the propagation of the incident, but nonetheless underscore the presence of fuel in the dust collection system that was ignored by Mr. Cholin in his analysis of the propagation of the explosion. In fact, neither Mr. Osborn nor Mr. Cholin opine on propagation of the explosion through dust collection systems, further evidencing their disregard for material inside equipment/ducts and underscoring the deficiencies in their opinions.

Brenton Cox

Brenton L. Cox, Ph.D., P.E., CFEI
Managing Engineer

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3 Expert Report of Mr. Cholin, January 21, 2023. p. 176.

4 Expert Report of Mr. Cholin, January 21, 2023. p. 180.

2 Introduction and Background

The next two subsections will introduce my qualifications and the scope of Exponent's investigation. This is followed by a background related to grain milling and some historical examples of dust explosions in the grain industry. Next is a summary of background details specific to Didion Milling Inc. (Didion) in Cambria, Wisconsin. Last is an event description beginning on Monday, May 29, 2017, and continuing through the explosion.

2.1 Qualifications of Dr. Brenton Cox

I am a Managing Engineer with Exponent. I received a B.S. in Chemical Engineering from the University of Florida in 2005 and a Ph.D. in Chemical Engineering from Cornell University in 2011. I am a licensed professional chemical engineer and a certified fire and explosion investigator (CFEI). I have over eleven years of experience investigating fires and explosions involving combustible dusts, flammable gases and vapors, and reactive materials in a variety of industries including agricultural and agro-industrial facilities.

I am an active leader and participant in the process safety community, regularly contributing to conferences and technical publications. I have presented papers at the Global Congress for Process Safety (GCPS), the Institute of Chemical Engineers Hazards Conference, and the Mary Kay O'Connor Process Safety Center International Symposium. In 2019, I served as chair of the Process Safety Management Mentoring Forum at the GCPS. I am a principal member of the National Fire Protection Association (NFPA) Technical Committee on Water-Cooling Towers (WAC-AAA) and also hold a credential in Grain Operations Management from the Grain Elevator and Processing Society (GEAPS).

I have authored or co-authored peer reviewed articles related to dust explosions, incident investigation, and loss prevention. I also co-authored a book chapter on Risk Assessment in Dust Explosions, a volume of Elsevier's series on Methods in Chemical Process Safety. Exponent charges $390 per hour for my services in 2023. My curriculum vitae, which includes my list of publications, is provided in Appendix B. My testimony list for the previous four years is in Appendix C.

2.2 Exponent Investigation Scope, Objectives, and Activities

Exponent was retained on June 1, 2017, to investigate the fire and explosion that occurred on May 31, 2017, at the Didion facility at 501 Williams Street in Cambria, Wisconsin. I performed my investigation in a manner consistent with the scientific method of fire investigation, which is described in NFPA 921: Guide for Fire and Explosion Investigations.[5]

[5] Note, there are two relevant editions of NFPA 921: Guide for Fire and Explosion Investigations. The 2017 Edition was effective from December 1, 2016, through the time of the incident. The 2021 Edition became effective on April 25, 2020, superseding the 2017 Edition. Hence, all references in this report are to the 2021 Edition.

I first arrived onsite at Didion on June 2, 2017. Recovery efforts were still ongoing and an inspection of the interior of the mill was not yet possible, but I performed an inspection of the perimeter of the facility and photographed the state of the exterior of the facility. Exponent returned on June 7 and June 9, 2017, to inspect portions of the facility, but the lower level of the B-Mill was not accessible until the week of June 13. Several limited entries were performed during the week of June 13, and a systematic inspection of the accessible portions of the milling areas was performed on June 20 and 21, 2017.

Exponent observed and photo-documented the controlled demolition activities conducted from July 2017 through October 2017, as well as the recovery and inspection of evidence. Items were documented and tagged by others, but the evidence logs were distributed prior to inspections of the evidence laydown yards. Ultimately, artifacts were moved offsite to a nearby property where sufficient space was available.

Exponent was present at Robinette Demolition's facility in Oakbrook Terrace, Illinois, when contractors for the U.S. Chemical Safety Board (CSB) packaged and loaded the North Bauermeister (NBM) and South Bauermeister (SBM) for shipment to Stress Engineering Services, Inc.'s Mechanical & Material Engineering Testing Facility in Waller, Texas, for destructive examination. Note, due to the size of this equipment, each required a separate flatbed and were shipped on separate occasions (January 7 and April 16, 2019). I attended the destructive examination of each Bauermeister from April 30 through May 2, 2019.

Product samples of Bran (8480 Fine Bran) and Pregelatinized Corn Meal (7400 Pregel) were collected on October 23, 2017, for testing and analysis. Material was sent to third-party laboratories for testing of particle size and composition (via proximate and ultimate analysis)[6] as well as several combustibility and explosibility-related parameters.[7]

D16931 - 0017, D16931 - 0030

Figure 1. Exponent sampling Didion Milling products for further testing and analysis: 8480 Fine Bran (left) and 7400 Pregel Corn Flour (right).

Exponent also reviewed documents provided by Didion and other parties to this matter.

[6] Mineral Labs Inc. Certificates of Analysis No.'s 17035482 and 17035483, dated December 18, 2017.

[7] IEP Technologies Combustion Research Center Determination of Combustion Characteristics of Two Process Dusts. Report No. CRC-4749. Issued January 18, 2018. Revised January 22, 2018.

2.3 General Background of Grain Milling

Industrial grain milling comprises several unit operations that separate, sort, grind, and size the different kernel components into final products.[8,9] The process begins with the shipment of whole grain to the mill, where it is stored in silos until it is sent through a cleaning process. The cleaning process may entail a series of separation equipment (Table 1), including screen separators, aspirators, magnetic separators, disc separators, scourers, and rotating drums. These pieces of equipment facilitate the removal of undesirable elements, such as metal, stones, sticks, and other grains

[8] Smyth S., Cox B., Hetrick T., Ogle R. (2019). Lessons learned from a milling explosion. J. Loss. Prev. Process Ind. 62, 103928. pp. 1-2.

[9] Williams G., Rosentrater K. (2007). Design Considerations for the Construction and Operation of Flour Milling Facilities. Part I: Planning, Structural, and Life Safety Considerations. pp. 1-2.

Table 1. Glossary of some terms employed in the grain milling industry

Equipment	Description	References[10,11,12,13,14,15,16,17]
Airlock	A type of feeder used to feed medium-pressure conveyors from a supply hopper. Also referred to as a rotary seal, rotary valve feeder, or star feeder.	Boumans 1985 § 4.6.3. Ortega-Rivas 2012 p. 160.
Aspirator	Applies air classification, or a method to separate powdery, granular, or fibrous materials in accordance with settling velocity, particle size, particle density, and particle shape.	Ortega-Rivas 2012 pp. 340-341.
Attrition or Gap Mill	Contains a high-speed rotor separated by a narrow gap from a stationary casing. The high speed of the rotor imparts substantial shear onto the material to achieve further size reduction.	Ortega-Rivas 2012 p. 191. Smyth et al. 2019 p. 2.
Bagger	Equipment used to fill bags with product.	REF-MILL-ENG-8202-01 Domestic Packaging System Process Flow S#02, HACCP.
Baghouse	A type of dust collector that employs a fabric filter to capture dust from an airstream with high efficiency.	NFPA FPH p. 92
Bin (or Silo)	A container or vessel generally shorter and wider than a silo. Note, colloquially, these two terms may be used interchangeably.	Ortega-Rivas 2012 p. 102.
Crusher (Coarse Grinder)	Classification of size reduction equipment for coarse reduction.	Ortega-Rivas 2012 p. 184.
Cyclone	Common gas-solid separation device that uses centrifugal force (no moving parts) to separate heavier material from lighter material (fines) mixed with air.	Ortega-Rivas 2012 p. 334. Smyth et al. 2019 p. 2.
Dust Collector	A type of gas-solid separators such as cyclones, bag-type filters (baghouse), and cartridge-type filters used to separate and concentrate dust from a dust-laden air stream.	Valiulis 1999 p. 99
Expander	Equipment used in the creation of pregelatinized corn products at the Didion Mill, involving the addition of water and/or steam.	HACCP

10 Boumans G. (1985). Grain Handling and Storage. Developments in Agricultural Engineering 4. Elsevier.

11 Ortega-Rivas E. (2012). Unit Operations of Particulate Solids. CRC Press.

12 Smyth S., Cox B., Hetrick T., Ogle R. (2019). Lessons learned from a milling explosion. J. Loss. Prev. Process Ind. 62, 103928.

13 Valiulis J. et al. (1999). Experiments on the Propagation of Vented Dust Explosions to Connected Equipment. Process Safety Progress. 18(2), pp. 99-106.

14 Williams G., Rosentrater K. (2007). Design Considerations for the Construction and Operation of Flour Milling Facilities. Part I: Planning, Structural, and Life Safety Considerations.

15 NFPA, Fire Protection Handbook, 20th Edition. 2008. Chapter 7.

16 Kice Industries Speed Spout Technical Manual.

17 Bepex Solidaire, https://www.bepex.com/products/solidaire/

Filter	A type of gas-solid separation typically placed downstream of a cyclone. Generally contains a porous fabric designed to separate fines from air.	Ortega-Rivas 2012 p. 345. Smyth et al. 2019 p. 2.
Gate	Controls release of flow from bins and hoppers to feeders or conveyors.	Ortega-Rivas 2012 p. 132.
Grinder	Classification of size reduction equipment employed principally in intermediate and fine reduction.	Ortega-Rivas 2012 p. 184.
Hammer Mill	A type of grinder for intermediate size reduction. Usually features a single rotating cylinder equipped with hammers that drive material against a breaker plate. Impact drives the extent of size reduction in normal operation.	Ortega-Rivas 2012 pp. 185-190. Smyth et al. 2019 p. 2.
Hopper	Small bin with a sloping bottom for temporary storage of solids before they are fed into a process.	Ortega-Rivas 2012 p. 102.
Lift Gate	A term used to refer to the Kice SGH Streamguard, which was used in the pneumatic conveying system at the Didion Mill.	Kice Technical Manual
Magnetic Separator	Removes small iron-containing pieces. The grate separator, drum separator, and belt separator are types of conventional magnetic separators.	Ortega-Rivas 2012 p. 303.
Mill	Classification of size reduction equipment generally used for all applications other than coarse reduction.	Ortega-Rivas 2012 p. 184.
Polisher / Finisher	Removes fine flour from coarse product.	KICE Industries Bran & Shorts Finisher Manual (DIDION0006695)
Roller Mill	A type of grinder for intermediate size reduction. Contains counter-rotating cylinders that impact, compress, and shear material.	Ortega-Rivas 2012 p. 185. Smyth et al. 2019 p. 2.
Scalper	Equipment used in the corn cleaning process to remove material that is undersized (“fines”), oversized (“overs”), and trash.	REF-MILL-ENG-3001-01Corn Cleaning System S#1, HACCP
Scourer	A scouring machine cleans the surface of grain to separate organic impurities.	http://spomax.pl/en/cleaner/
Screen Separator	Sieve with mesh sizes ranging from µm (microns) to cm (centimeters) in particle diameter. Effective at controlling particle size distribution in the effluent.	Ortega-Rivas 2012 p. 77.
Sifter	Mechanical process that separates material according to particle size.	Great Western Manufacturing, Full Line Brochure.
Silo (or Bin)	A container or vessel used to store grain. A silo suggests a structure that is taller than a bin, but these two terms may be used interchangeably in reference to bulk storage vessels at Didion.	Ortega-Rivas 2012 p. 102.
Solidaire	Paddle dryer used in material processing at Didion Milling.	Bepex (https://www.bepex.com/products/solidaire/)
Tempering Bin	Concrete or steel bins used for storing whole grains in the clean and preclean bins.	Williams 2007 p. 15.
Tumbling Mill	A type of grinder for intermediate size reduction. Contains a horizontal, slow-speed, rotating cylinder partially filled with balls or rods to achieve fine grinding.	Ortega-Rivas 2012 pp. 185, 191-192.

Air is a key utility in grain milling facilities, as it is used to transport grain from system to system and to separate streams into components.[18] The air system comprises fans, blowers, compressors, and pneumatic conveying lines. Screens and magnets can be used further downstream in the process to divide product streams or enable further capturing of foreign debris. Cyclones can be used to separate heavier material from lighter material (known as fines) mixed with air. The fine-laden air is fed to filters to help separate those fines from air. Such cyclones and filters (bag-type and cartridge-type) are also referred to as dust collectors.[19]

After cleaning, grain is transported to tempering bins to soak kernels in water, maintaining a relatively consistent moisture content in the kernels.[20,21] This soaking softens the endosperm and strengthens the outer bran, facilitating their separation later in the process. The milling process begins after the tempering stage and includes a series of size reduction equipment designed to break apart the kernels into its constituent pieces—bran, endosperm, and germ—and break those coarse pieces down into finer ones. The major types of size reduction equipment include roller mills, hammer mills, and attrition mills (Table 1). Note that "Bauermeister" is a company that manufactures such equipment, including gap mills, roller mills, impact mills, and grinders.[22]

Roller mills are often used for the "first break," or first stage of the milling process, as they typically result in the coarsest output of material. During the first break, the roller mills mechanically separate the endosperm from the other parts of the kernel (bran and germ), and this mixture is sent to a purification system to separate endosperm from the bran and germ. Hammermills usually feature a single rotating cylinder equipped with hammers that drive material against a breaker plate. If a hammer mill outlet becomes plugged or choked, then shear (attrition) forces may become appreciable. Attrition (or gap) mills leverage shear forces to achieve further size reduction, sometimes generating an appreciable amount of heat due to the high-speed rotor.

2.4 Grain Industry Dust Explosion Background and History

For a fire to occur, fuel, oxygen (or another oxidizer), and an ignition source must come together into an ignition sequence.[23] The three components constitute the historical "fire triangle"—a fire cannot occur unless these three components come together into an ignition sequence.[24] More recent industry guidance incorporates this fourth leg, an ignition sequence

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18 Williams G., Rosentrater K. (2007). Design Considerations for the Construction and Operation of Flour Milling Facilities. Part I: Planning, Structural, and Life Safety Considerations. p. 3.

19 Valiulis J. et al. (1999). Experiments on the Propagation of Vented Dust Explosions to Connected Equipment. Process Safety Progress. 18(2), pp. 99-106.

20 Smyth S., Cox B., Hetrick T., Ogle R. (2019). Lessons learned from a milling explosion. J. Loss. Prev. Process Ind. 62, 103928. p. 2.

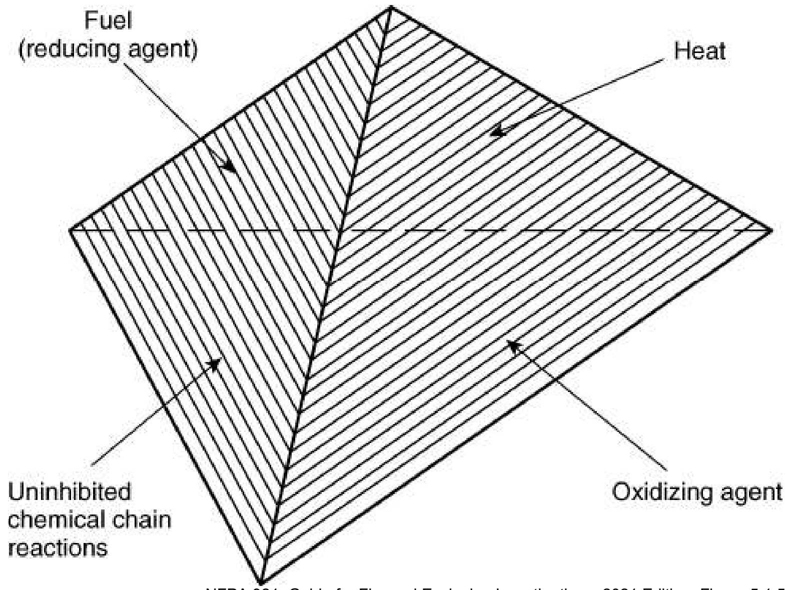
21 Williams G., Rosentrater K. (2007). Design Considerations for the Construction and Operation of Flour Milling Facilities. Part I: Planning, Structural, and Life Safety Considerations. pp. 1-2.

22 Bauermeister USA. https://bauermeisterusa.com/, accessed March 21, 2023.

23 NFPA 921: Guide for Fire and Explosion Investigations, 2021 Edition, 19.4.4.1.

24 For example, see NFPA 61, Figure A.5.2.

(i.e., the initiation of "uninhibited chemical chain reactions"), turning the "fire triangle" into a "fire tetrahedron," shown in Figure 2.[25]



NFPA 921: Guide for Fire and Explosion Investigations, 2021 Edition, Figure 5.1.5.

Figure 2. Fire tetrahedron showing the (1) fuel, (2) heat (ignition source), and (3) oxidizing agent (e.g., oxygen) that must come together in an ignition sequence, initiating (4) uninhibited chemical chain reactions.[26]

Many of the commodities handled in the grain industry consist of organic material that can burn if exposed to an ignition source. If finely divided and suspended to a sufficient concentration, the material may be combustible in air. Finely divided, combustible particulate solids are known as combustible dusts.[27,28] The minimum concentration that a suspension of combustible dust is capable of being ignited is known as the minimum explosible concentration (MEC).[29] Ignition of a suspension of combustible dust above its MEC may result in a deflagration, a propagating fire that travels at a velocity less than the speed of sound.[30] A deflagration within a confined

[25] NFPA 921: Guide for Fire and Explosion Investigations, 2021 Edition, 5.1.5.

[26] NFPA 921: Guide for Fire and Explosion Investigations, 2021 Edition, Figure 5.1.5.

[27] NFPA 652: Standard on the Fundamentals of Combustible Dust, 2019 Edition, 3.3.6.

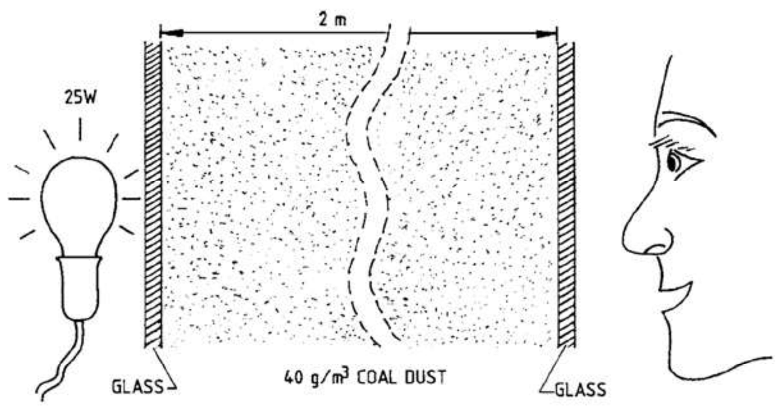
[28] Note, the term "dust" in the context of combustible dust refers to the particle size associated with the materials and should not be confused with household dust. NFPA 652 defines dusts as material 500 µm or smaller (i.e., capable of passing through a U.S. No. 35 standard sieve).

[29] NFPA 921: Guide for Fire and Explosion Investigations, 2021 Edition, 3.3.134.

[30] NFPA 921: Guide for Fire and Explosion Investigations, 2021 Edition, 3.3.44.

space may result in an explosion, e.g., the rapid conversion of potential energy (chemical or mechanical) into kinetic energy with the production and release of gases under pressure."[31]

For Didion's Fine Bran product (Fine Bran 8480) the MEC was determined to be 120 g/m^3.[32] This concentration is several orders of magnitude greater than the levels of dust that may represent an industrial hygiene concern.[33] As a point of comparison, an oft-quoted rule of thumb is that a glowing 25-Watt lightbulb cannot be seen through a 2-meter-thick dust cloud at a concentration above 40 g/m^3. While this heuristic uses coal dust as an example, the MEC for Fine Bran product would be three times as dense.



Eckhoff, p. 9.

Figure 3. Illustration of the rule of thumb that a 25-Watt lightbulb cannot be seen through 2 meters of a 40 g/m^3 cloud of coal dust. Note, the MEC of Didion's bran product was 120 g/m^3.

Dust explosions often occur in series: an initial or "primary" explosion (deflagration) generates a pressure wave, which is followed by a flame front.[34] If the flame front finds additional fuel in an ignitable mixture with air, e.g., in the form of pneumatic conveying or dust collection lines or a pulsed-jet baghouse, then the flame may persist. The initial pressure wave can suspend surface deposits of fuel within equipment or outside of it. If sufficient fuel is suspended to form an ignitable mixture, it will allow the flame to propagate. The pressure wave may also serve to compress the fuel/air mixture prior to the arrival of the flame, which increases the speed of the flame, and for ducts that are very long relative to their diameter (e.g., L/D > 100), it *can* result in a deflagration-to-detonation transition, but this is far from a certainty.[35] The pressure wave may

31 NFPA 921: Guide for Fire and Explosion Investigations, 2021 Edition, 22.1.3.

32 IEP Technologies Combustion Research Center Determination of Combustion Characteristics of Two Process Dusts. Report No. CRC-4749. Issued January 18, 2018. Revised January 22, 2018.

33 Eckhoff, R. Dust Explosions in the Process Industries, 3rd Ed. pp. 8-9.

34 Ogle R. (2017). Dust explosion dynamics. Elsevier. pp. 18-24.

35 Ogle R. (2017). Dust explosion dynamics. Elsevier. pp. 548-550.

also compress the fuel in vessels in advance of the flame front, thus increasing the magnitude of the explosion that would have otherwise occurred, a phenomenon called "pressure piling." [36]

Internal propagation from the origin of the primary explosion between interconnected equipment is a known phenomenon that can result in flame acceleration. In this scenario, a blast wave that has initiated within a piece of process equipment propagates through internal ducting to other areas of the facility.[37] Ducting and equipment may contain suspended material in the flammable range when the flame arrives, or the propagating pressure wave may suspend the dust prior to arrival of the flame. This internal propagation of dust explosions through interconnected vessels has been studied extensively.[38,39,40,41] This phenomenon is relevant in the context of grain processing facilities given that equipment such as dust collection systems and distributors are intricately connected throughout areas of the facility and can be effective in multiplying the paths of explosion propagation.[42,43]

Circumstances in which the primary explosion causes equipment to rupture inside a room containing sufficient fugitive dust[44] can result in subsequent explosions often referred to as "secondary explosions."[45] The typical progression of these scenarios involves the primary explosion releasing a pressure wave followed by a flame into a room containing deposits of combustible dust. The pressure wave lifts a fraction of the lingering dust into suspension, and the propagating flame from the primary explosion subsequently ignites the suspended dust cloud.[46]

During an investigation of a secondary dust explosion event, the absence of fugitive dust or presence of unperturbed fugitive dust is consistent with the internal propagation mechanism discussed above. The presence of collapsed ductwork can also be indicative of internal

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[36] Ogle R. (2017). Dust explosion dynamics. Elsevier. § 9.4 Pressure Piling.

[37] Abbasi T., Abbasi S. (2007). Dust explosions–Cases, causes, consequences, and control. J. Haz. Mat. 140, p. 19.

[38] Holbrow P. et al. (1996). Dust explosions in interconnected vented vessels. J. Loss Prev. Process Ind. 9(1), pp. 91-103.

[39] Lunn G. et al. (1996). Dust explosions in totally enclosed interconnected vessel systems. J. Loss. Prev. Process Ind. 9(1), pp. 45-58.

[40] Kosinski P., Hoffman A. (2005). Dust explosions in connected vessels: Mathematical modeling. Powder Technology. 155, pp. 108-116.

[41] Ogle R. (2017). Dust explosion dynamics. Elsevier. § 10.5.2 Interconnected Vessels.

[42] Valiulis J. et al. (1999). Experiments on the Propagation of Vented Dust Explosions to Connected Equipment. Process Safety Progress. 18(2), pp. 99-106.

[43] National Materials Advisory Board. (1983). Guidelines for the Investigation of Grain Dust Explosions. p. 32.

[44] OSHA Grain Standard, 29 CFR 1910.272(c), defines the term "fugitive grain dust" as "combustible dust particles, emitted from the stock handling system, of such size as will pass through a U.S. Standard 40 mesh sieve (425 microns or less)." Note, this term does not include grain and product spills (per 1910.272(j)(4)).

[45] Note there is debate in the technical community as to whether the term "secondary explosion" should be used exclusively to refer to explosions involving fugitive dust. To avoid this confusion, this report uses the term "subsequent explosions" except when referring to explosions that follow a primary explosion and are fueled by deposits of fugitive dust.

[46] Zalosh R. et al. (2005). Safely Handle Powdered Solids. Chem. Eng. Prog. 101(12), pp. 23-30.

propagation. Collapsed ductwork can occur due to propagation of dust deflagrations through ducts under the right circumstances.[47] Generally, these circumstances include the formation of a partial vacuum from propagation of expansion waves inside the duct; however, an externally applied overpressure could also cause ductwork to collapse.

The following sections detail case studies featuring propagating dust explosions with elements that relate to that of the subject incident.

2.4.1 Dust explosion via internal propagation at a flour milling operation

Smyth et al. (2019) describe an anonymized case study involving a flour milling operation that suffered a large explosion event (Figure 4).[48] A deflagration initiated in the attrition (or gap) mill (which was manufactured by Bauermeister, as was the piece of milling equipment at the heart of this case). The deflagration then propagated internally through over seven stories of ducting to a mill filter, where an access hatch was blown off. Pressure piling may have occurred as the deflagration propagated, resulting in overpressure in the filter. Figure 5 depicts some portions of the facility damaged during the event. Notably, the facility did not contain any apparent fugitive dust accumulations, either in affected or in unaffected areas. Very little evidence of combustion activity existed outside of equipment, but many pieces of equipment showed signs of internal damage. Internal propagation through ducts was the only discernable mechanism by which the deflagration could have propagated to the mill filter.

Figure 4. Photographs of the resulting damage from the explosion at the flour milling facility discussed in Smyth et al. (2019).[49]

[47] Cox B., Hietala D., Ogle R. (2021). Dust explosions and collapsed ductwork. J. Loss. Prev. Process Ind. 69, 104350.

[48] Smyth S., Cox B., Hetrick T., Ogle R. (2019). Lessons learned from a milling explosion. J. Loss. Prev. Process Ind. 62, 103928.

[49] Smyth S., Cox B., Hetrick T., Ogle R. (2019). Lessons learned from a milling explosion. J. Loss. Prev. Process Ind. 62, 103928.

Figure 5. Damage to a set of filter socks, box sifter, filter, and first break cyclone (clockwise from top left) in the flour mill facility explosion discussed in Smyth et al. (2019).[50]

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[50] Smyth S., Cox B., Hetrick T., Ogle R. (2019). Lessons learned from a milling explosion. J. Loss. Prev. Process Ind. 62, 103928.

2.4.2 Dust explosion via internal propagation at Hayez Lemmerz International in 2003

On October 29, 2003, a propagating explosion occurred at Hayes Lemmerz International in Huntington, Indiana.[51,52] The CSB found numerous pieces of evidence of subsequent dust explosions caused via internal propagation and concluded that internal propagation played a significant role in exacerbating the damage from the incident.[53] An aluminum dust explosion in the dust collector was the initiating event. After the initiating event, the explosion then internally propagated from the dust collector to the drop box, causing it to rupture (Figure 6, Figure 7). This drop box could have experienced significantly higher pressure than the dust collector through pressure piling. From the drop box, a pressure wave entered the dust duct system, internally propagating through ducts and pipes in different directions to the fume separator (Figure 8, Figure 9, Figure 10), dry chip hopper, wet ship hopper, and furnace side well. In several instances, the pressure wave suspended accumulated dust internal to ducts and pipes, and the dust subsequently ignited from the propagating deflagration.

The CSB determined that the fireball that erupted from the equipment, engulfing nearby personnel, was the result of internal propagation. The CSB also concluded that a secondary explosion occurred after internal propagation exited a feed pipe. However, the CSB report did not connect this secondary explosion to the fatal injuries.

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[51] Taveau J. (2012). Secondary Dust Explosions: How to Prevent them or Mitigate their Effects? Proc. Safety Prog. 31, pp. 36-50.

[52] U.S. Chemical Safety and Hazard Investigation Board. (2005). Investigation Report No. 2004-01-I-IN on Aluminum Dust Explosion at Hayes Lemmerz International, Inc.

[53] U.S. Chemical Safety and Hazard Investigation Board. (2005). Investigation Report No. 2004-01-I-IN on Aluminum Dust Explosion at Hayes Lemmerz International, Inc. pp. 30-39.

Figure 6. Fragment of drop box after internal propagation from the dust collector occurred during the incident at Hayes Lemmerz International in 2003.[54]

[54] U.S. Chemical Safety and Hazard Investigation Board. (2005). Investigation Report No. 2004-01-I-IN on Aluminum Dust Explosion at Hayes Lemmerz International, Inc. p. 34.

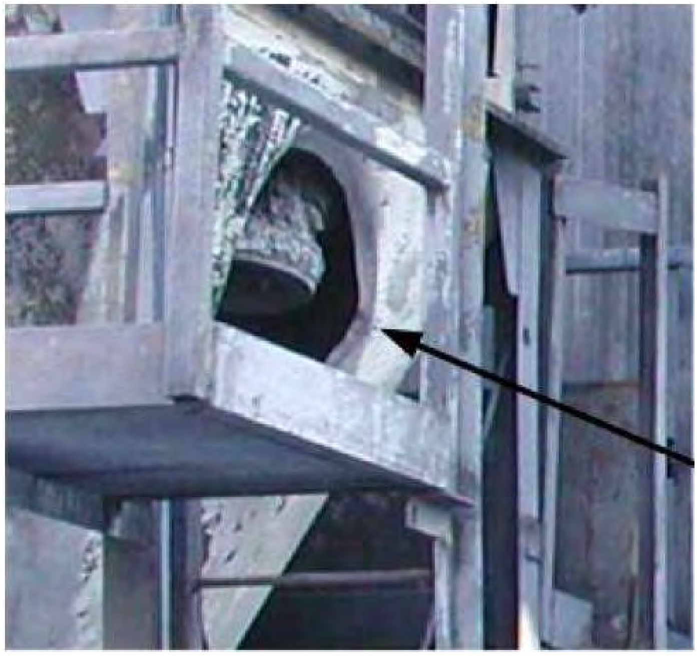


Figure 7. Photograph after the incident at Hayes Lemmerz International in 2003 indicating the short duct that used to connect the drop box to the dust collector before being pulled away by the propagating blast wave.[55]

[55] U.S. Chemical Safety and Hazard Investigation Board. (2005). Investigation Report No. 2004-01-I-IN on Aluminum Dust Explosion at Hayes Lemmerz International, Inc. p. 34.

Figure 8. Fume hood exhaust fan cover damaged by deflagrations inside the ducting and fan housing during the incident at Hayes Lemmerz International in 2003.[56]

[56] U.S. Chemical Safety and Hazard Investigation Board. (2005). Investigation Report No. 2004-01-I-IN on Aluminum Dust Explosion at Hayes Lemmerz International, Inc. p. 38.

Figure 9. Cleanout door on the duct from a fume hood to fume separator. The door was blown open as a result of internal propagation during the incident at Hayes Lemmerz International in 2003.[57]

[57] U.S. Chemical Safety and Hazard Investigation Board. (2005). Investigation Report No. 2004-01-I-IN on Aluminum Dust Explosion at Hayes Lemmerz International, Inc. p. 39.

Figure 10. Interior of duct from a fume hood to fume separator near the cleanout door. The CSB identified hard deposits and dust consistent with internal propagation during the incident at Hayes Lemmerz International in 2003.[58]

2.4.3 Dust explosion via internal propagation at Yeosu Industrial Complex in 2013

On March 14, 2013, a series of explosions occurred at the Yeosu Industrial Complex in Yeosu, South Korea.[59] The primary explosion occurred in a silo when flammable material inside it was inadvertently ignited by welding sparks during hot work installation of a manhole. The heat and shock waves generated in this silo “spread to neighboring silos through the piping connected to the outlet of the HDPE powder bag filter,” resulting in a subsequent explosion.

58 U.S. Chemical Safety and Hazard Investigation Board. (2005). Investigation Report No. 2004-01-I-IN on Aluminum Dust Explosion at Hayes Lemmerz International, Inc. p. 39.

59 Pak S. et al. (2019). Case Studies for Dangerous Dust Explosions in South Korea during Recent Years. Sustainability. 11, 4888.

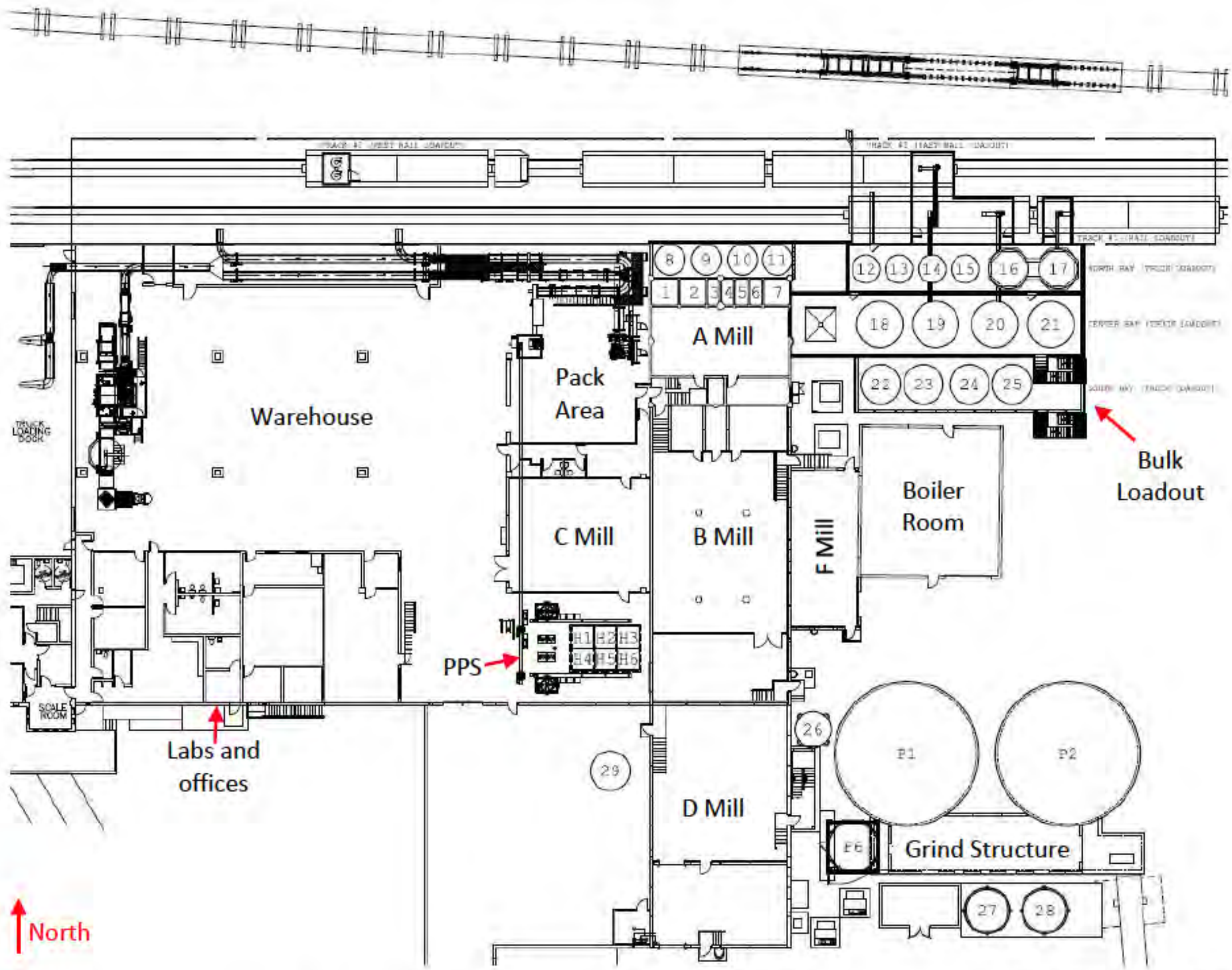
Figure 11. Photographs of the silo where the primary explosion initiated (left) and of a silo bottom affected by sudden impact (right) after the incident at the Yeosu Industrial Complex in 2013.[60]

2.5 Background of Didion Milling

Didion Milling was founded in 1972, but the first structure at the Cambria, Wisconsin, facility was constructed in 1991.[61] Additional structures were added over time, resulting in the mill structure depicted in Figure 12, consisting of adjacent and interconnected processing buildings referred to as the A-Mill, B-Mill, C-Mill, D-Mill, and F-Mill. Trucks and railcars were loaded directly with product in Bulk Loadout. Product was packaged in the Pack Area and the Product Protection System (PPS) Area. Packaged products were loaded in the rail and truck loading areas on the north and west sides of the Warehouse, respectively. Offices and laboratory space were located southwest of the Warehouse in a multi-floor structure housed within the larger building.

[60] Pak S. et al. (2019). Case Studies for Dangerous Dust Explosions in South Korea during Recent Years. Sustainability. 11, 4888.

[61] Didion Milling, History. http://www.didionmilling.com/the-didion-difference/history/, accessed June 1, 2017.



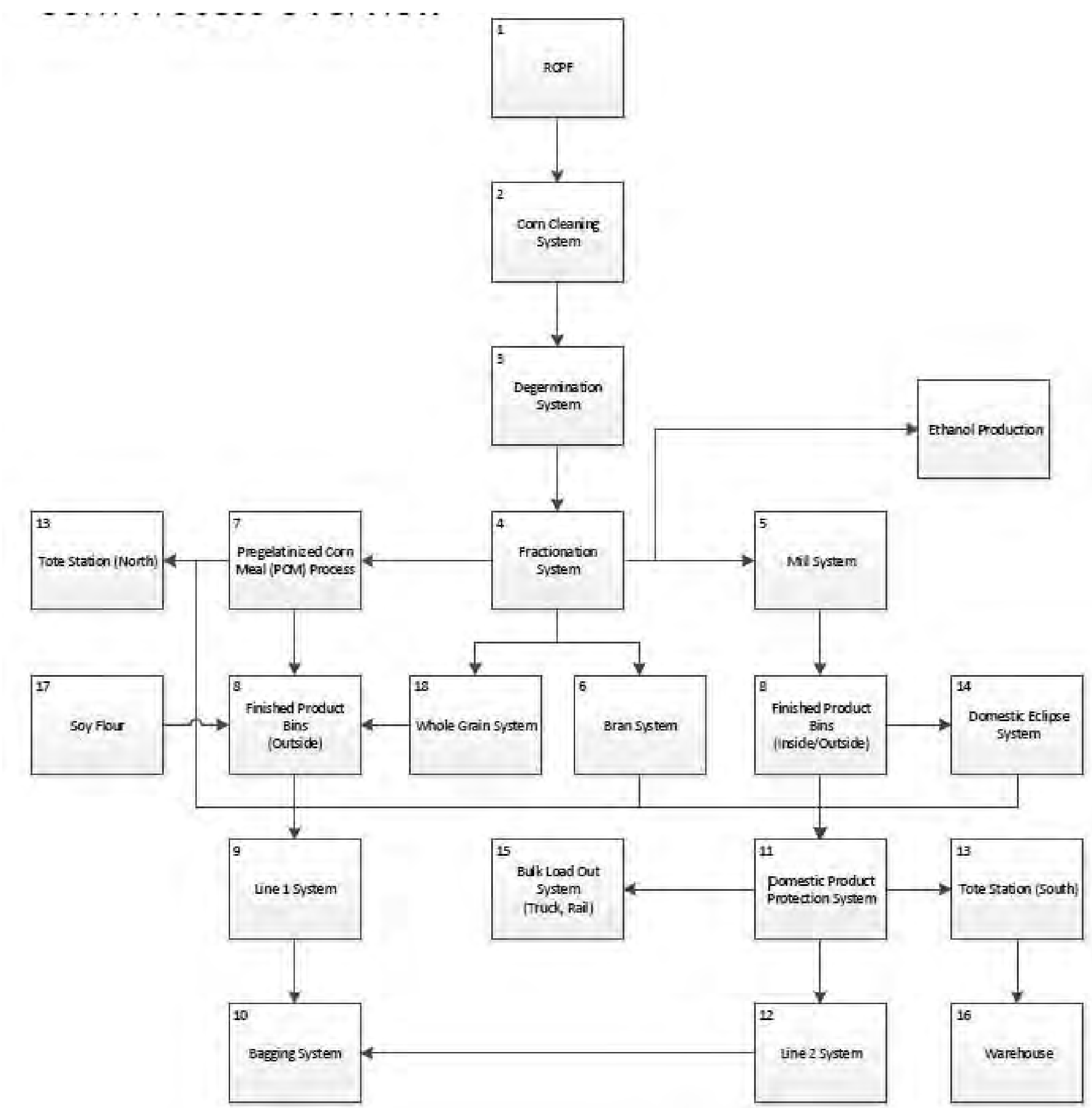
Adapted from DIDION0000017

Figure 12. Plot plan of the Didion Milling facility in Cambria, Wisconsin.[62]

2.5.1 Didion Products and Overall Process Description

There were multiple process systems at the Didion mill for processing raw corn. An overview of the Didion corn cleaning, fractionation, and milling processes is shown below in Figure 13.

[62] Bulk Storage and Loadout Bin Guide, Process Flow Diagram. REF-MILL-ENG 0002-01 Rev 2016-F. DIDION0000017.



REF-MILL-FS-0001 HACCP Process Flow rev6.0 2015.05 28.pdf

Figure 13. Didion Overall Process Overview.

The overall process was comprised of the following systems which spanned across multiple buildings throughout the mill:[63]

1. RCPF – Raw Corn Processing Facility
2. Corn Cleaning System

[63] REF-MILL-FS-0001 HACCP Process Flow rev6.0 2015.05.28.pdf

3. Degermination System
4. Fractionation System
5. Mill System
6. Bran System
7. Pregelatinized Corn Meal (PCM), NCS 83 and Pregel Process (e.g., Expander Systems)
8. Finished Products Bins Overview
9. Line 1 System
10. Bagging System
11. Domestic Product Protection System
12. Line 2 System
13. Tote Station
14. Domestic Eclipse System
15. N Bulk Loadout System, C Bulk Loadout System, S Bulk Loadout System
16. Warehouse
17. Soy Flour
18. Whole Grain System

Raw corn was received and processed. Except for whole grain products, which were processed in the Whole Grain System, the corn was fractionated into its constituent parts—bran, germ, and endosperm.[64] The bran is directed to the Bran System. The endosperm is used to manufacture grits, corn meal, and flour. Flour may be further processed to form pregelatinized corn products that are cooked at high temperature and then further processed. The systems most relevant to this investigation are described in greater detail in subsequent sections.

Removal of unwanted fine particulates is an important aspect of operations, although it is not specifically identified in the Process Overview shown in Figure 13. These fines were removed through various processing equipment described above, e.g., sifters and polishers, and were separated from process streams using air/material separators, e.g., cyclones. Fines from cyclones and other sources were typically sent to one of a number of fabric air/material separators (i.e., "dust collectors"). The material collected at these dust collectors and other settled fines were sent to a feed conveyor to be used at the neighboring ethanol facility.

Two of the most relevant dust collectors to this investigation are the Torit, located in the F Mill, and the Dry Grit Filter, located outside of the D-Mill. Several other dust collectors were utilized throughout the building to perform air-material separation.

2.5.2 Didion Bran System

The Bran System was used to produce Bran at different granulations (fine and coarse) as well as different total dietary fiber (TDF) content. The system consisted of Bran Collection & Drying,[65]

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[64] Didion Milling, Family of Corn Products. http://www.didionmilling.com/dry-corn-mill/corn-products, accessed June 1, 2017.

[65] Bran System Sheet 1 of 3, Process Flow Diagram. REF-MILL-ENG 4201-01 Rev 2015-0.

Primary Flour Removal,[66] and Secondary Flour Removal and Grinding.[67] These processing activities took place primarily in the B-Mill and D-Mill.

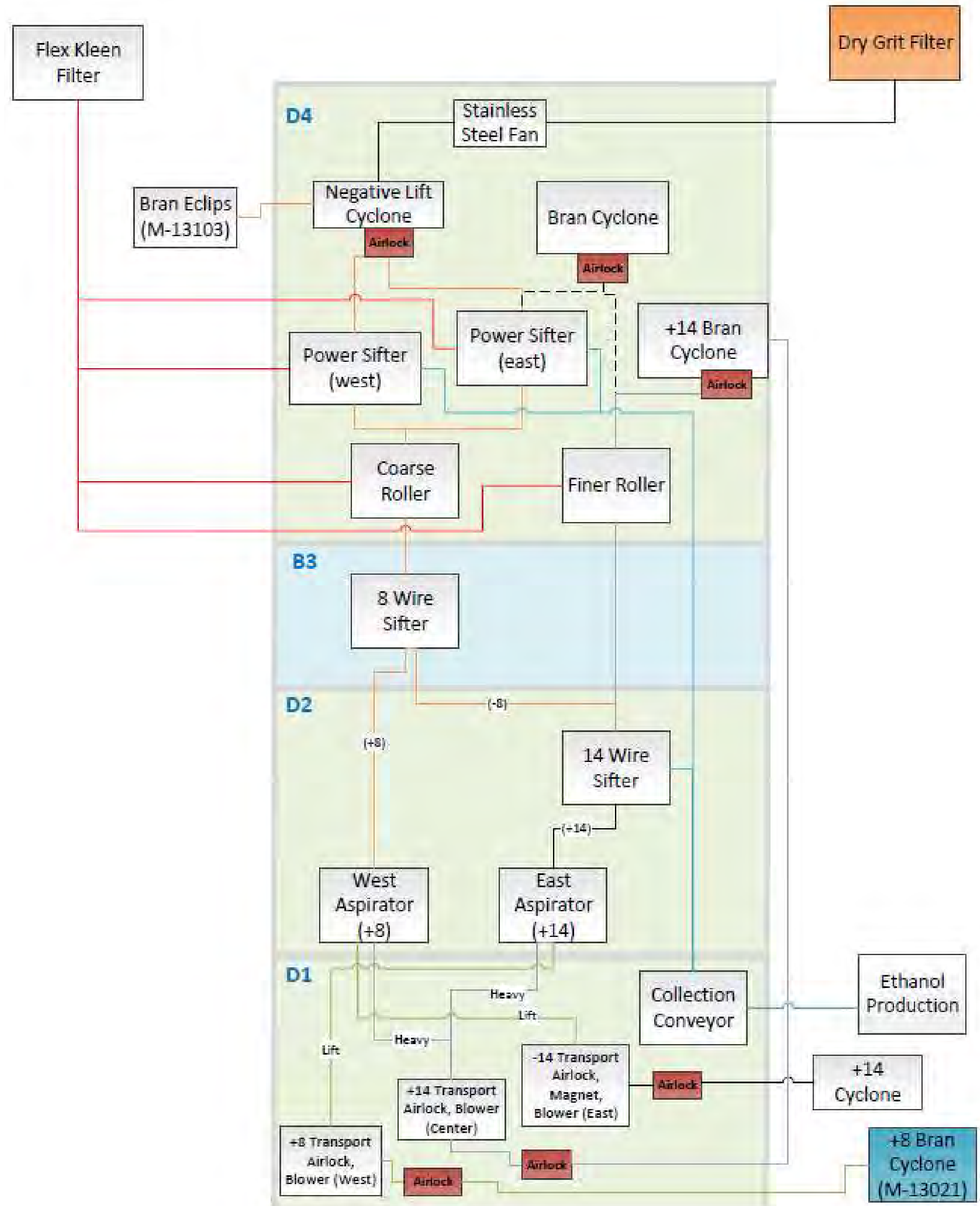
Bran Collection & Drying took place in the D-Mill and is not shown below. Material was fed from different portions of the Fractionation System to equipment in the D-Mill. Material passed through one of several aspirators and/or cyclones before being dried in the Bran Eclipse located on D2. From the Bran Eclipse, material was conveyed under negative lift to the Primary Flour Removal portion of the Bran System. Many of the systems in the mill were oriented vertically and used gravity to convey material from one piece of equipment to the next. Separation and conditioning were primarily performed on the higher levels of the mill buildings, and much of the grinding equipment was located in the lower levels. Ground material was then conveyed to product bins or recycled to the top floors for further separation and conditioning.

Representative Primary Flour Removal and Secondary Flour Removal Process Flow Diagrams (PFDs) are shown below in Figure 14 and Figure 15, respectively. These PFDs were adapted from documents provided by Didion, including more detailed PFDs that were highlighted by Didion employees to identify the state of the process at the time of the incident.[68]

[66] Bran System Sheet 2 of 3, Process Flow Diagram. REF-MILL-ENG 4202-01 Rev 2015-0.

[67] Bran System Sheet 3 of 3, Process Flow Diagram. REF-MILL-ENG 4203-01 Rev 2015-0.

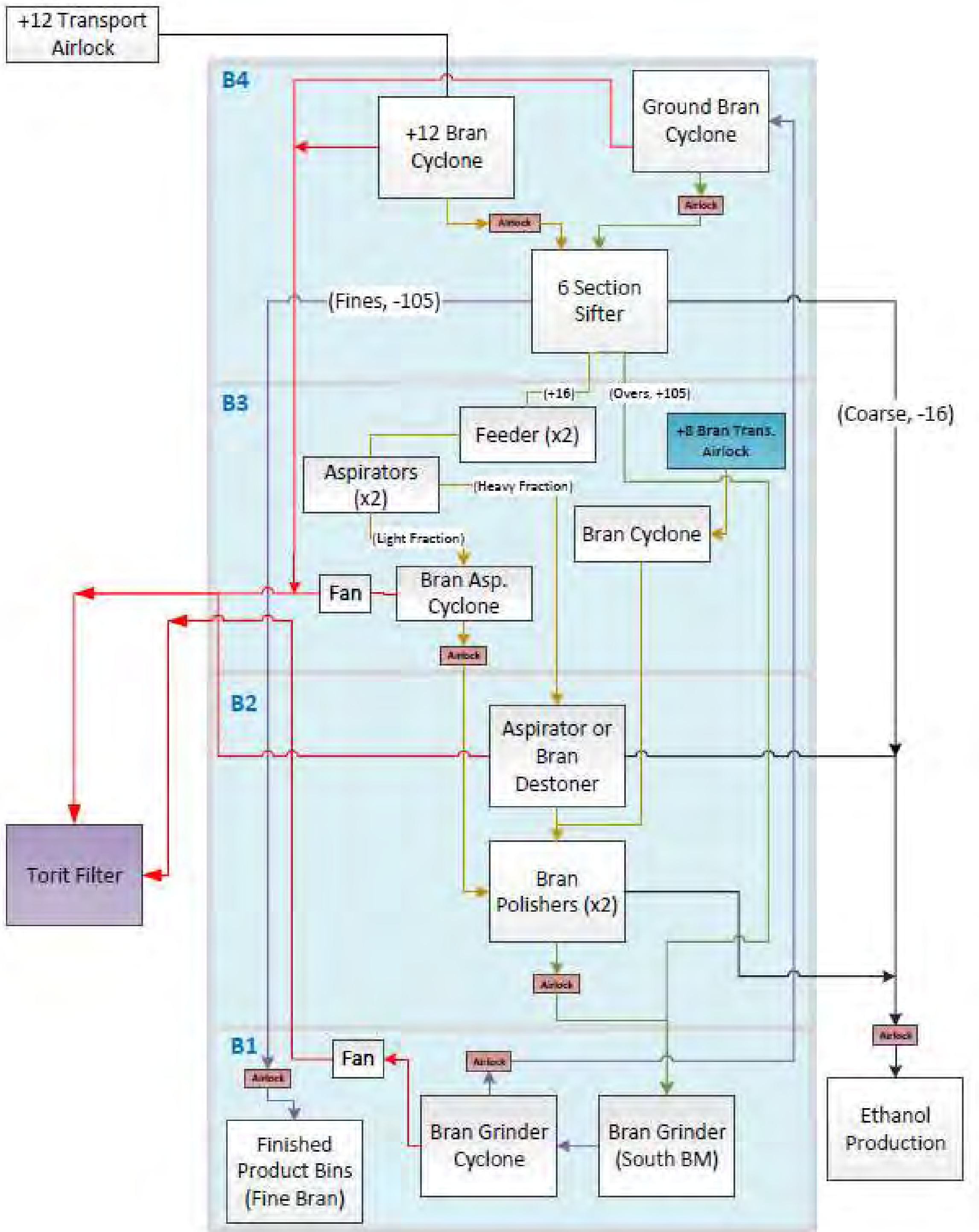
[68] Highlighted PFDs – Bran System.



Adapted from Highlighted PFDs - Bran System pdf and REF-MILL-ENG-4202-01 Bran System S#2 pdf

Figure 14. Bran Processing System (Primary Flour Removal) PFD in D-Mill.[69]

[69] Bran System Sheet 2 of 3, Process Flow Diagram. REF-MILL-ENG 4202-01 Rev 2015-0.



Adapted from Highlighted PFDs - Bran System.pdf and REF-MILL-ENG-4203-01 Bran System S#3.pdf

Figure 15. Bran Processing System (Secondary Flour Removal and Grinding) PFD in B-Mill.[70]

[70] Bran System Sheet 3 of 3, Process Flow Diagram. REF-MILL-ENG 4203-01 Rev 2015-0.

Not shown in the PFDs is a Management of Change (MOC) performed on May 3rd, 2017, which allowed for the incorporation of the NBM into the Bran System.[71] The change managed by this MOC was the connection of the "North Bauermeister blower line after [the] cyclone airlock to South Bauermeister cyclone airlock to use both [B]auermeister's for bran production."

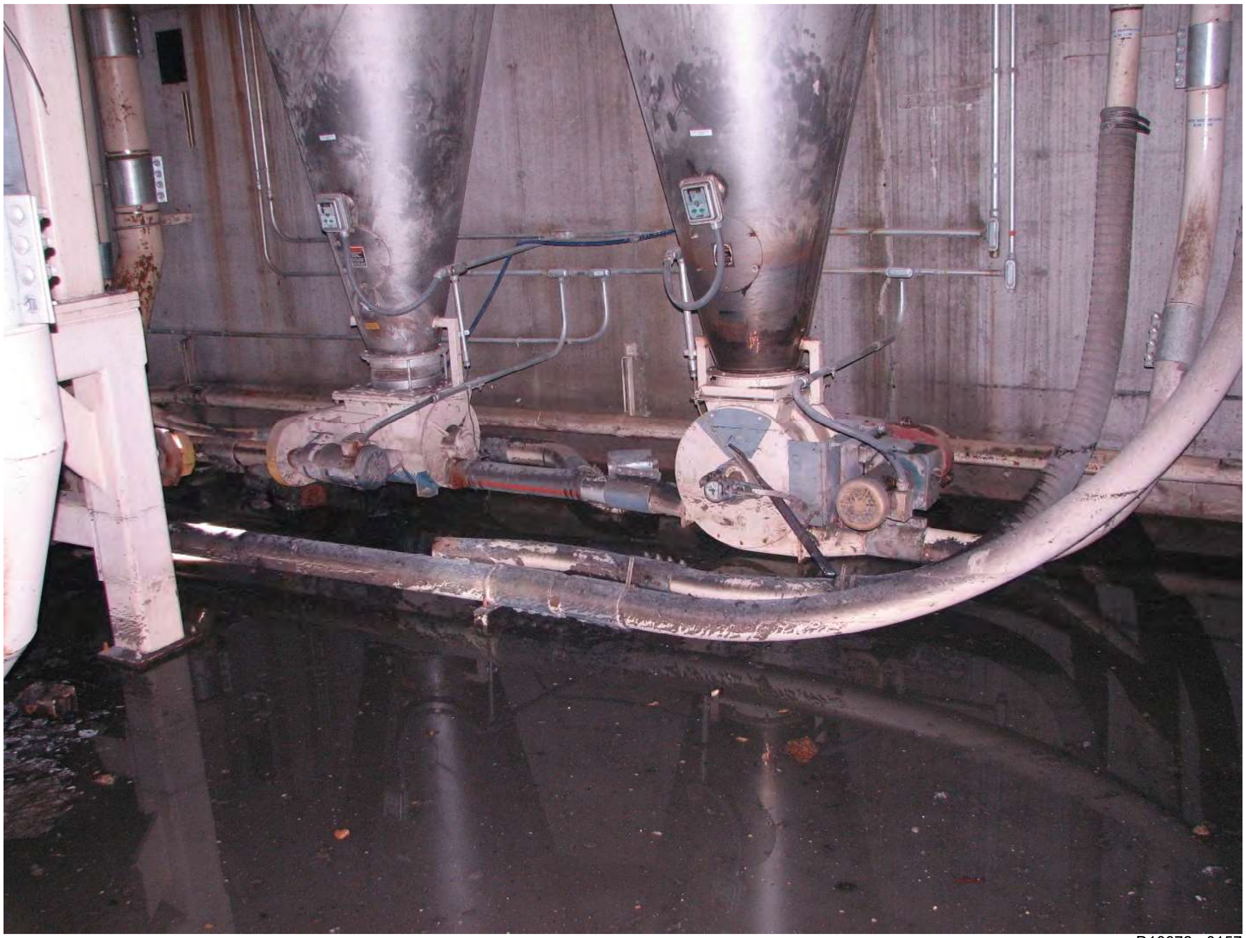


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Figure 16. Picture the as-found configuration, combining the discharge of the SBM Cyclone (left) and NBM Cyclone (right).

2.5.3 Torit Dust Collection System

The Torit Dust collector was a dust collection system that was installed for dust collection across A-Mill, F-Mill, and B-Mill. This dust collection system was connected to equipment across the Bran and Fractionation Systems[72] in the B-mill, Corn Cleaning System[73] in the F-

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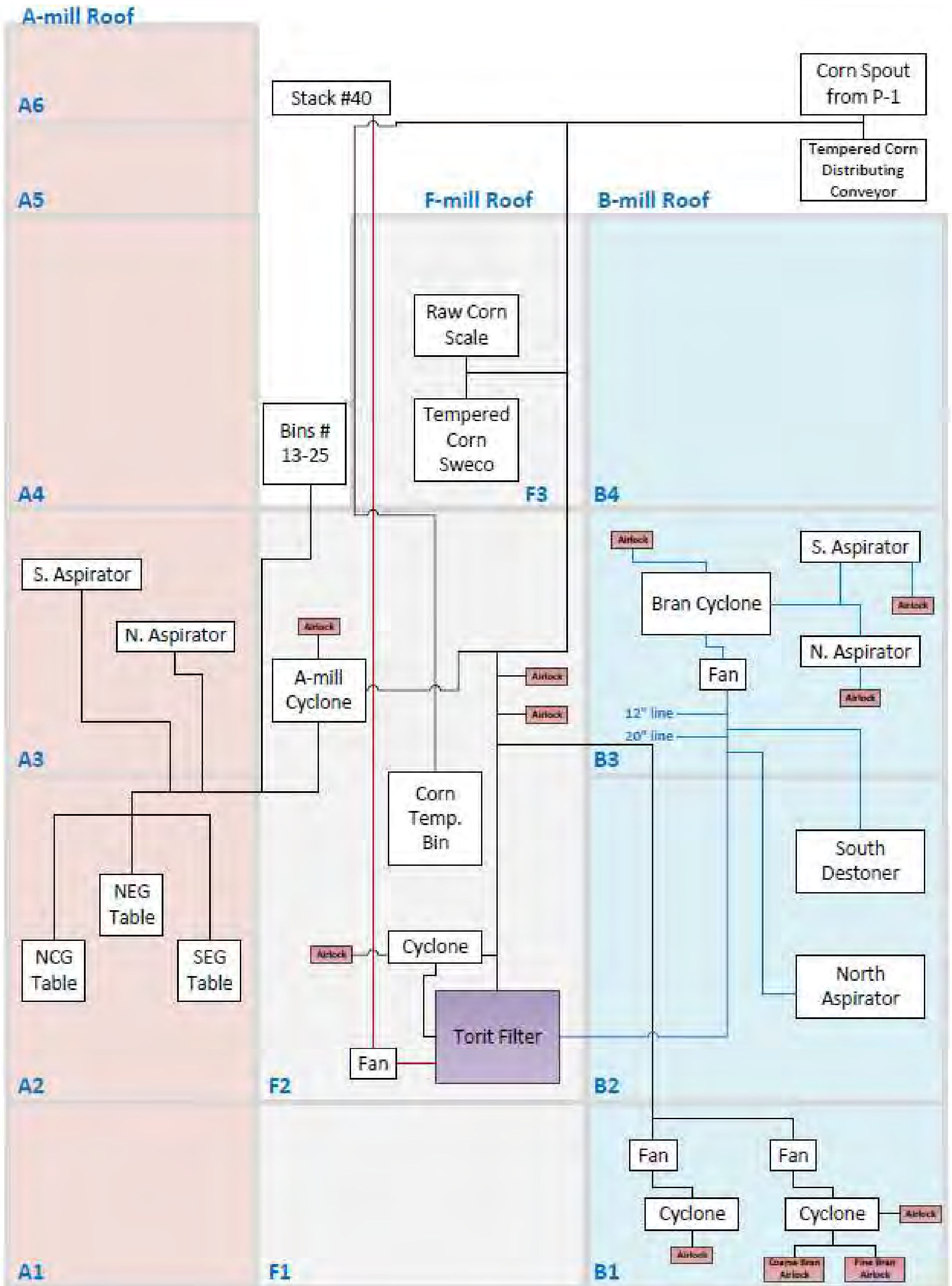
71 Management of Change, Addition of North Bauermeister to Bran System. DIDION0002560-7.

72 Highlighted PFDs - Bran System.pdf.

73 Highlighted PFDs - Fractionation.pdf, REF-MILL-ENG-3001-01Corn Cleaning System S#1.

Mill, and various ducting in the A-mill.[74] This system was essential for the dust collection and safe operation of the equipment.

[74] F2 Torit Filter, Process Flow Diagram. REF-MILL-ENG-7801-01 Rev FINAL.



Adapted from REF-M LL-ENG-7801-01 F3 Torit Filter S#1.pdf

Figure 17. Torit Filter System PFD across A-Mill, F-Mill, and B-Mill.[75]

[75] F2 Torit Filter, Process Flow Diagram. REF-MILL-ENG 7801-01 Rev FINAL.

2.5.4 F6 Dry Grit Dust Collection System

The Dry Grit Dust Collection System, i.e., the dust collection system feeding the Dry Grit Filter, served equipment across the Warehouse, B-Mill, D-Mill, A-Mill, and Grind Structure. This dust collection system was connected to equipment across the Bran System[76] in the B- and D-mill[77] as well as various ducting in the PPS system in the warehouse and Mill System (ultimately producing flour products from dry grit)[78] in the A-Mill (although not shown in the PFD).[79,80]

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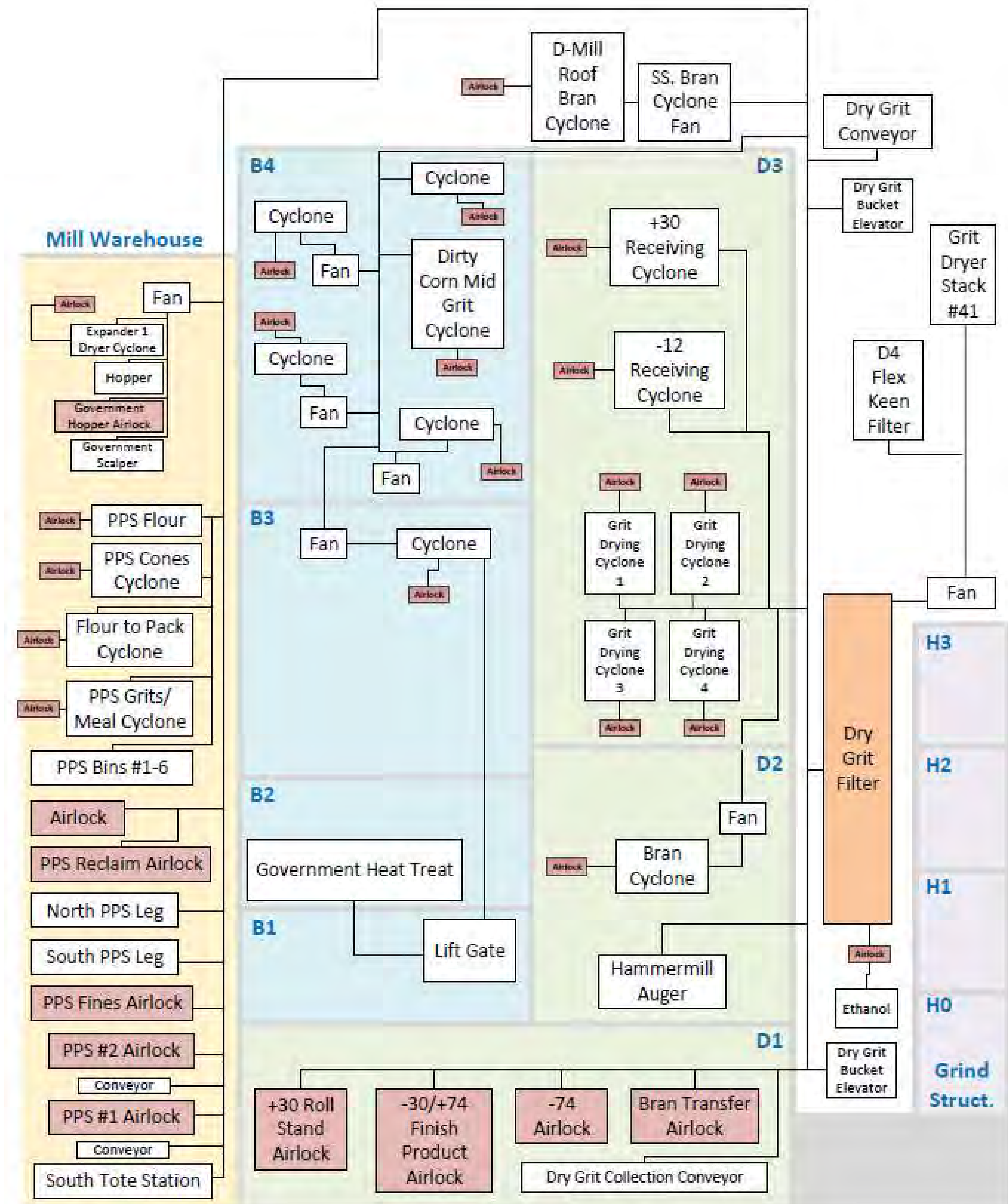
76 Highlighted PFDs - Bran System.pdf

77 Grit Drying System, Process Flow Diagram. REF-MILL-ENG 4601-01 Rev 2015-0.

78 HACCP, p. 7.

79 F6 Dry Grit Filter, Process Flow Diagram. REF-MILL-ENG 7803-01 Rev FINAL.

80 A-Mill Systems, Process Flow Diagram. REF-MILL-ENG 5001-01 Rev FINAL.



Adapted from REF-MILL-ENG-7803-01 F6 Dry Grit Filter S#3 pdf and Highlighted PFDs - Government Heat Treat and LO.pdf

Figure 18. Dry Grit Filter System PFD Across Warehouse, B-Mill, D-Mill, and Grind Structure.[81,82]

[81] F6 Dry Grit Filter, Process Flow Diagram. REF-MILL-ENG 7803-01 Rev FINAL.

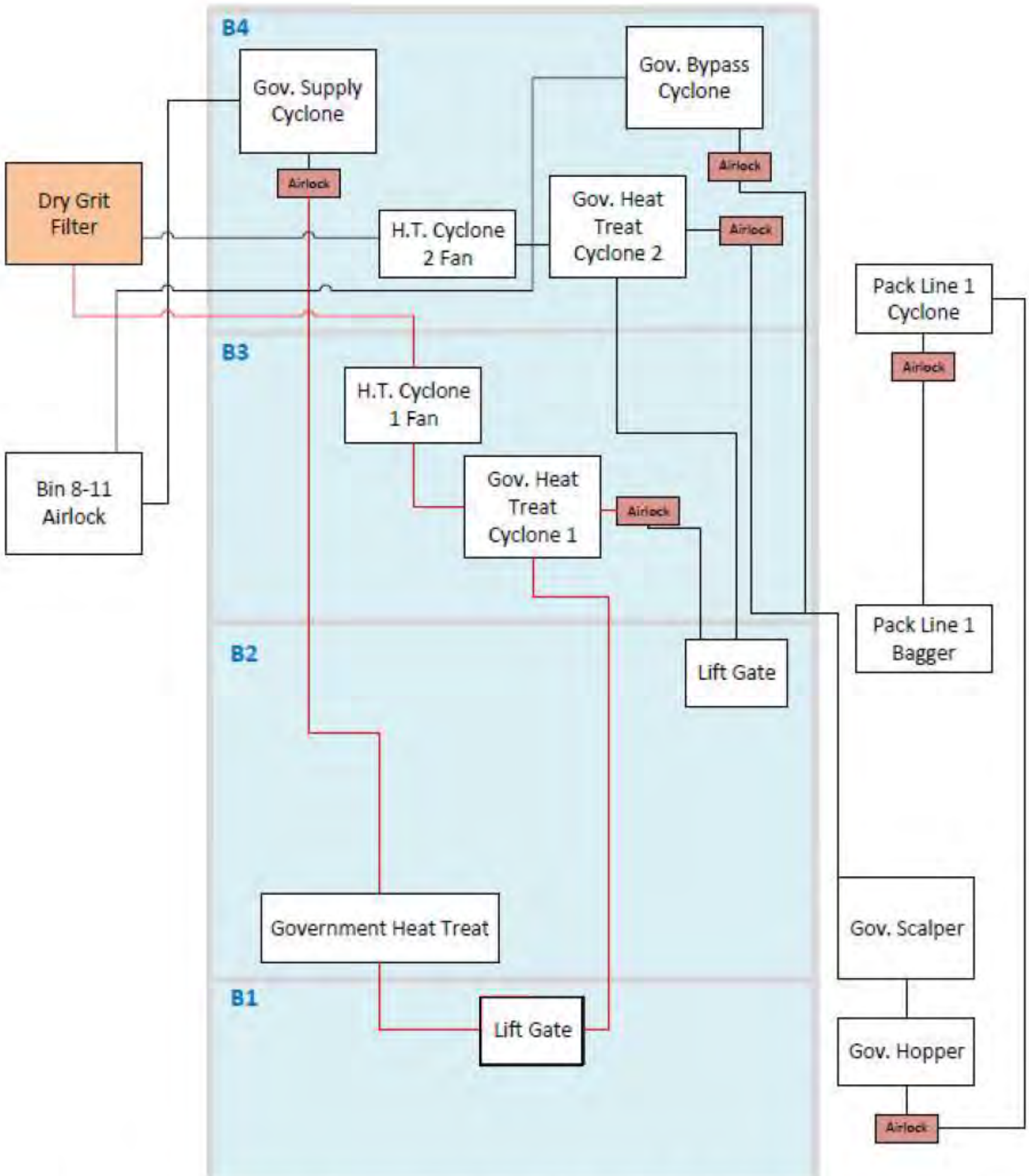
2.5.5 Government Heat Treat System

The Government Heat Treat System was used to make products to United States government specifications for international aid projects, e.g. CM6 cornmeal[83], which was being made on the day of the incident.[84] This system was primarily located in the B-Mill where the Government Heat Treat Eclipse and multiple cyclones were located with their fans and lift gates. This system's PFD is shown below in Figure 19.

[82] Government Packaging System, Process Flow Diagram. REF-MILL-ENG 8601-01 Rev 2015-0.

[83] USDA Commodity Requirements for CM6 Cornmeal for Use in International Food Assistance Programs. https://www.ams.usda.gov/sites/default/files/media/cm6.pdf, accessed March 31, 2023.

[84] DIDION0001877



Adapted from Highlighted PFDs - Government Heat Treat and LO pdf and REF-MILL-ENG-8601-01 Gov Packaging System Process Flow S#01 pdf

Figure 19. Government System PFD in B-Mill.[85]

[85] Government Packaging System, Process Flow Diagram. REF-MILL-ENG 8601-01 Rev 2015-0.

2.6 Event Description

2.6.1 Events of May 29, 2017

On May 29, 2017, facility personnel made several attempts to start Expander 5 in the C Mill.[86] During the last attempt around 2:32 PM, the temperatures in the Expander 5 Dryer rose to levels above normal operating conditions. Around 3:45 PM, an employee noticed a burning smell originating from the Dryer. Burned product was located in the 4B spreader shortly thereafter, and all three exhaust temperatures started to rise, triggering high temperature alarms.

At around 4 PM, an employee noticed fire in the Dryer. Another employee then shut down the Expander 5 system, including the Coarse Grinder (CG) which was removed from service. Fire extinguishers were then deployed, staff was evacuated, and 911 was contacted. The fire department arrived around 4:23 PM.[87] The fire in the Dryer was extinguished by 5 PM; however, another fire began in the filter on the roof around 5:10 PM (Figure 20). This second fire was also extinguished after the fire department eventually was able to flow water onto the filter about an hour later. Around this time, the fire department personnel performed a walkthrough with the millers and verified that the B-4 Spreader, B-3 Sifter, and B1 CG exhibited no hot spots. Bin 9 and P1 were also inspected, and thermal imaging found nothing of concern. The mill was released back to Didion at around 8:48 PM. The mill was restarted about an hour later; however, the CG remained offline for the subsequent investigation (Figure 21).

[86] Didion Root Cause Analysis – Incident Timeline for May 29, 2017. DIDION0006367.

[87] Cambria Fire NFIRS-1 Basic Report, May 29, 2017. GJ_CFD_0000061.

Figure 20. Fire in the Expander 5 filter on May 29, 2017.[88]

[88] Client-supplied image "1.jpg".

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Figure 21. View of the Coarse Grinder in the Expander 5 system. The outlet remained disconnected following the events on May 29, 2017.

2.6.2 Events of the Morning of May 31, 2017

There were no remarkable observations in the shift notes on May 30, 2017.[89] On the morning of May 31, 2017, Expander 1 service was switched to PCM+, a pregelatinized cornmeal product, from NCS, another extruded product.[90,91] The team noticed a burning smell. Upon investigation, it was observed that the Expander 1 Bliss Hammer Mill seemed hotter than usual and was not operating as expected. In response, facility personnel shut down the hammer mill and removed all product from it. Some of the product was black and/or smoldering. The hammer mill and its bearings were inspected by maintenance personnel before returning it to service around 4 PM. By 5:15 PM, finished product was lined up to go to the storage bin.

89 DIDION0001876.

90 Email from Justin Dalton to Derrick Clark, June 21, 2017.

91 E.g., NCS 83 Safety Data Sheet (DIDION0000037).

D16682 - 0138

Figure 22. View of the Expander 1 Bliss Hammer Mill.

2.6.3 Status of Mill during the Afternoon of May 31, 2017

Several processes were in operation at the time of the incident based on the Mill & Extrusion Production Report for the second shift, which began at 6 PM.[92] Three grades of corn meal were being processed: two grades of fine corn meal and CM6 Government cornmeal. GM Rebolt Cones were in production, and two grades of flour were being processed: Rebolt (Heat Treat) and 5A Sifter (Heat Treat). PCM+ was being produced in Expander #1. At the start of the shift, Expanders 3 and 4 were being used in the production of Pregel, but they were taken offline at 8:15 PM. Expander 3 was brought back online at 9:15 PM to produce NCS, although no production samples were prior to the 11 PM explosion.

On May 31, 2017, the South Bauermeister (SBM) was operating in the Bran System, as was typically the case. The North Bauermeister (NBM) began the day in NCS service but was switched to Bran service when Expander 1 was switched from NCS service to PCM+.[93] Feed was halted to both BMs while maintenance was performed elsewhere in the facility, from about 1:00 to 2:00.[94] Both BMs returned to normal operation by about 2:30 PM and operated without remark until later in the evening.[95] From about 10:13 PM to 10:51 PM, the temperature in the

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92 DIDION0001877.

93 DIDION0001877.

94 DIDION0001877.

95 DCS Data on May 31, 2017: SBM Temperature 1 (TT1-13030; DIDION0001619), SBM Temperature 2 (TT2-13030; DIDION0001626), NBM Temperature 1 (TT1-13031; DIDION0001620), NBM Temperature 2 (TT2-13031; DIDION0001627), SBM Motor Amps (VFD-13030, DIDION0001709), NBM Motor Amps (VFD-13031, DIDION0001710).

SBM gradually rose from about 170 to 182°F, concurrent with an increase in motor amps and decrease in vibration (Figure 23).[96] At about 10:45 PM or 10:50 PM, operators reported smoke and began searching for its source (see Section 2.6.4). At around 10:53 PM, the SBM temperature spiked to 193°F with a spike in fan amps occurring just before. The explosion occurred at about 11:00 PM following a small decrease in fan amps. At 11:01 PM, all data ceased.

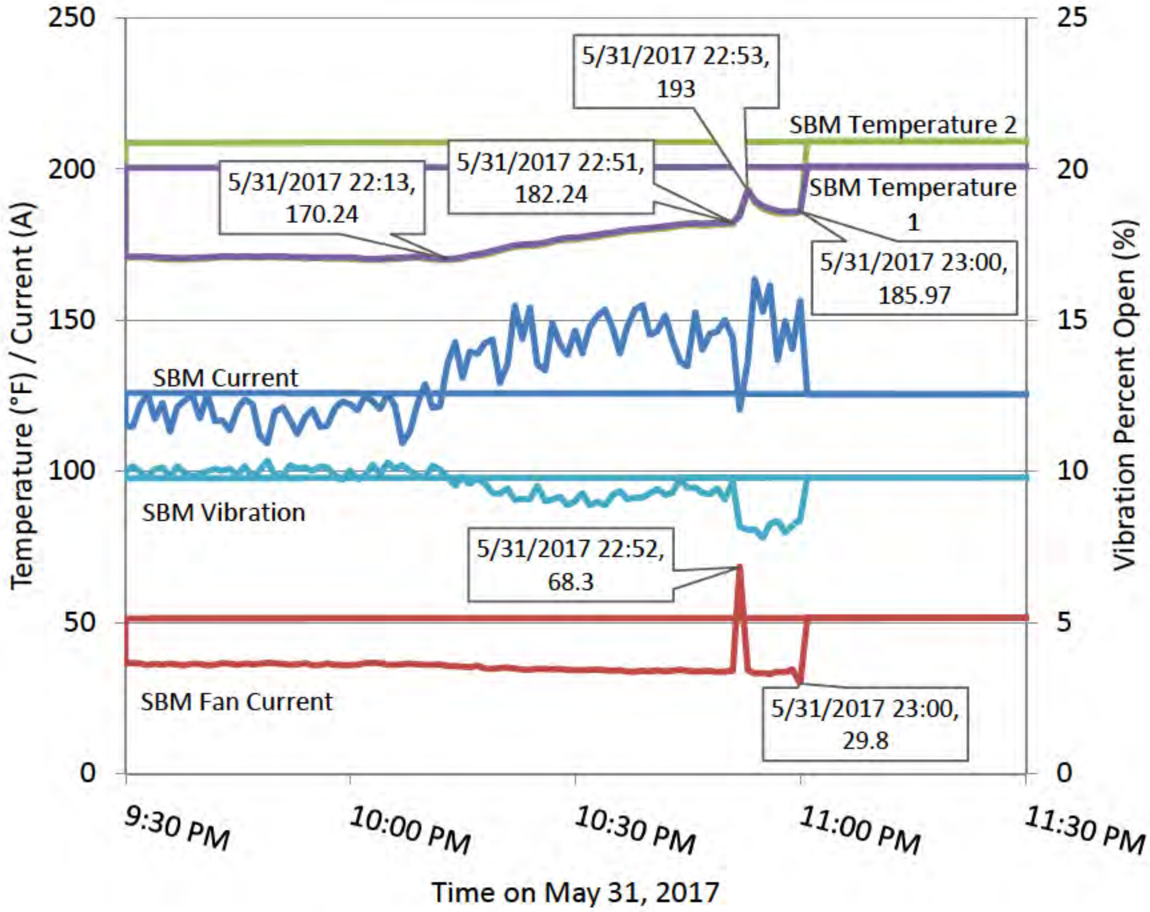

Figure 23. Temperatures, currents (amps), and vibrations recorded for the South Bauermeister (SBM) on the evening of May 31, 2017.[97]

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[96] C f., SBM Motor Amps (VFD-13030, DIDION0001709), NBM Motor Amps (VFD-13031, DIDION0001710).

[97] DCS Data on May 31, 2017: SBM Temperature 1 (TT1-13030; DIDION0001619), SBM Temperature 2 (TT2-13030; DIDION0001626), SBM Motor Amps (VFD-13030; DIDION0001709), SBM Vibration (VB-13030; DIDION0001663, DIDION0024370), SBM Fan Amps (VFD-13034; DIDION0001711).

2.6.4 Witness Observations

On May 31, 2017, the day shift pack crew began work at 6 AM as normal.[98] Due to the fire that occurred on May 29, 2017 (see Section 2.6.1), there was less product available to pack than normal. As a result, the pack crew spent a portion of their shift cleaning from about 2 or 3 PM to 6 PM (end of shift). According to [redacted] testimony,[99] two packers cleaned A1 and two packers cleaned B1. This cleaning included the floors (sweeping, shovels, mops) and using air guns to spray some of the elevated surfaces of machines.

During the night shift on May 31st, three millers were present–Bruno Ponto Real,[100] Duelle Block, and Rene Alva (miller's assistant)[101]—and the Superintendent, Hayden Dodge.[102] According to [redacted], sometime between 10:30 and 10:50 PM, it was reported over the radio that smoke was emanating from B1.[103,104] Several personnel were in the mill office at the time (Location 1, Figure 24),[105] including Mr. Real, Adolfo Aguirre Alvarez, Mr. Dodge, and possibly Pawell Tordoff.[106,107,108] [redacted] exited the mill office out of the west door to look for smoke, unsuccessfully, while the others traveled to the mill to determine the source of the smoke. [redacted] searched for smoke on the second floor, then A1, and then B1, where he identified the smell of smoke.[109]

98 U.S. Chemical Safety and Hazard Investigations Board Interview of [redacted]. June 15, 2017. pp. 3, 13-16, 18, 29-30. GJ_CSB_0004501, GJ_CSB_0004511-4, GJ_CSB_0004516, GJ_CSB_0004527-8.

99 U.S. Chemical Safety and Hazard Investigations Board Interview of [redacted]. June 15, 2017. pp. 3, 13-16, 18, 29-30. GJ_CSB_0004501, GJ_CSB_0004511-4, GJ_CSB_0004516, GJ_CSB_0004527-8.

100 Deposition Transcript of [redacted], May 13, 2021. p. 151.

101 Deposition Transcript of [redacted], May 24, 2021. p. 8.

102 U.S. Chemical Safety and Hazard Investigations Board Interview of [redacted]. July 11, 2017. p. 2. GJ_CSB_0005683.

103 Deposition Transcript of [redacted], May 13, 2021. p. 112.

104 U.S. Department of labor Employee Interview Statement, [redacted], July 20, 2017. p. 2. DM0004498.

105 Deposition Transcript of [redacted], May 13, 2021. p. 120.

106 U.S. Chemical Safety and Hazard Investigations Board Interview of [redacted] July 11, 2017. p. 3. GJ_CSB_0005684.

107 Wisconsin Department of Justice DCI Interview of [redacted]. June 14, 2017. p. 2. WDOJ_000379.

108 Deposition Transcript of [redacted], May 13, 2021. p. 151.

109 U.S. Chemical Safety and Hazard Investigations Board Interview of [redacted] September 20, 2017. p. 4. GJ_CSB_0004984.

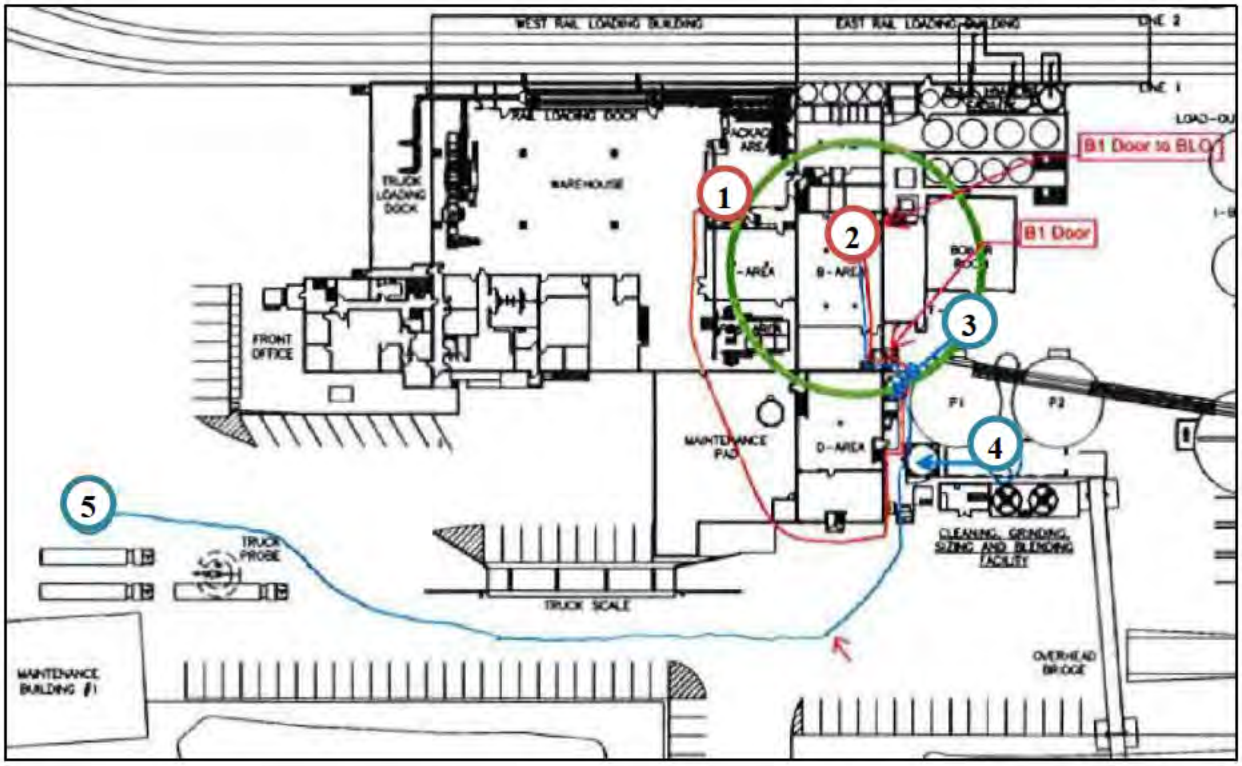

Figure 24. Facility map indicating the paths traveled by [redacted] immediately preceding (red path from 1 to 2) and during (blue path from 2 to 5) the incident. Top of figure is North.[110]

[redacted] walked around the south end of D-Mill to the east side of the mill (Red line connecting Locations 1 and 2, Figure 24).[111,112] It was reported over radio that smoke was found in B1, so [redacted] traveled to the South East door to B1 ("B1 Door", Figure 24).[113] As soon as [redacted] opened this door, he observed "lingering, really thin smoke on the…ceiling."[114,115] The smell of the smoke was unique and unlike smells [redacted]dge had experienced previously at the mill. [redacted] recounted a smell resembling that of a belt or metal burning, different from that of product burning.[116] Around this time, [redacted] encountered Mr. Nunez arriving from the bulk loadout, and Mr. Alvarez, Mr. Alva, and Mr. Block (a miller)

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[110] Exhibit 2 to Deposition Transcript of [redacted], May 13, 2021.

[111] U.S. Chemical Safety and Hazard Investigations Board Interview of [redacted]. July 11, 2017. p. 3. GJ_CSB_0005684.

[112] Deposition Transcript of [redacted], May 13, 2021. p. 124.

[113] Deposition Transcript of [redacted], May 13, 2021. pp. 124-125.

[114] U.S. Chemical Safety and Hazard Investigations Board Interview of [redacted]. July 11, 2017. p. 4. GJ_CSB_0005685.

[115] Wisconsin Department of Justice DCI Interview of [redacted]. June 14, 2017. p. 2. WDOJ_000379.

[116] U.S. Chemical Safety and Hazard Investigations Board Interview of [redacted]. September 20, 2017. p. 5. GJ_CSB_0004985.

traveling from the mill through the north stairwell, all into B1.[117,118,119,120,121] They were all attempting to locate the source of the smoke; however, the smoke did not appear to be flowing from anywhere but instead lingering in place.

The group investigated the room for about two to five minutes.[122,123] [redacted] checked the hammer mill in B1 without noticing anything unusual.[124] They then checked the Bauermeisters. [redacted] noted that the SBM felt warmer to the touch than the NBM; however, [redacted] did not believe the temperature difference was concerning at the time.[125,126] The group did not identify the source of smoke, so [redacted] suggested that the group should disperse into different rooms in the mill to identify the source of smoke. [redacted] exited the room while Mr. Dodge, Mr. Alva, and Mr. Nunez remained.[127,128,129,130]

Around 11 PM, approximately one to two minutes after [redacted] told the group to disperse from B1, he heard a "huge boom" and a "constant…consistent roar" while standing near the pre-gel hammer mill.[131,132] The SBM air-intake suction line[133] filter "blew off" and flew through the air.[134,135] At this point he noticed a 3- to 6-foot, blue-and-yellow, skinny, torch flame

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117 U.S. Chemical Safety and Hazard Investigations Board Interview of [redacted]. July 11, 2017. pp. 4-5. GJ_CSB_0005685-6.

118 Wisconsin Department of Justice DCI Interview of [redacted]. June 14, 2017. p. 2. WDOJ_000379.

119 There are discrepancies in witness statements regarding who went to B1 and for how long, immediately preceding the incident. [redacted]

120 Deposition Transcript of [redacted] May 13, 2021. p. 151.

121 Deposition Transcript of [redacted], May 24, 2021. pp. 10, 12, 89-90.

122 Deposition Transcript of [redacted] May 13, 2021. pp. 128-129.

123 Deposition Transcript of [redacted], May 24, 2021. p. 90.

124 U.S. Chemical Safety and Hazard Investigations Board Interview of [redacted]. September 20, 2017. p. 4. GJ_CSB_0004984.

125 U.S. Chemical Safety and Hazard Investigations Board Interview of [redacted]. July 11, 2017. pp. 4-5. GJ_CSB_0005685-6.

126 Deposition Transcript of [redacted], May 13, 2021. pp. 129-130.

127 Although [redacted] initially recounted that Mr. Nunez also exited B1 at this time, he later indicated that he believed Mr. Nunez remained in B1 based on information he obtained later.

128 U.S. Chemical Safety and Hazard Investigations Board Interview of [redacted]. July 11, 2017. p. 6. GJ_CSB_0005687.

129 Deposition Transcript of [redacted], May 13, 2021. pp. 131, 212-213.

130 [redacted] Interview Statement to OSHA with Translation. August 28, 2017. p. 9. DM0004421.

131 Deposition Transcript of [redacted], May 13, 2021. pp. 112, 133-137.

132 U.S. Chemical Safety and Hazard Investigations Board Interview [redacted]. July 11, 2017. p. 6. GJ_CSB_0005687.

133 Also referred to as the air inlet or the vacuum line.

134 U.S. Chemical Safety and Hazard Investigations Board Interview of [redacted]. July 11, 2017. p. 8. GJ_CSB_0005689.

"shooting out of the [8-in air] intake of the suction line that…takes product from that [South] Bauermeister to the cyclone."[136,137] The flame reached the celling and persisted for about five seconds before "it sucked back in."[138] The force of the flame and/or "boom" perturbed and loosened dust on horizontal pipes near the ceiling, causing it to "mist" down. In one interview, [redacted] estimated that this perturbed dust layer on overhead pipes was originally as "thick as [his] phone."[139] At this point, [redacted] and [redacted] looked across the room at each other in shock.[140] Several seconds later, the flame reappeared.[141] During this time, [redacted] was across the room from [redacted] communicating to Mr. Real (who was in the mill office at the time) over radio that he should turn off the SBM.[142,143] When the flame reappeared, [redacted] communicated across the room to [redacted] that they should evacuate.[144] According to [redacted] Mr. Nunez exited via a different door (Top right corner of B-Area in Figure 24).[145]

2.6.4.1 Status of [redacted] after the Initial Events of B1

After the decision to evacuate B1 was made, [redacted] exited the way that he entered, reaching the South East door to B1 ("B1 Door", Figure 24) within what he estimated to be about 5 seconds.[146] Shortly after [redacted] exited that door, about 10 to 20 steps away near Bin 26 (Location 3; Figure 24),[147] he heard Mr. Nunez communicating over radio in Spanish that there was a fire in B1.[148,149] [redacted] later testified that he believed that Mr. Nunez was either in B1 at this time or exiting B1 through the door toward the bulk loadout ("B1 Door to BLO", Figure 24).[150] When the radio channel cleared, [redacted] communicated over radio in English that there was a fire and that everyone should evacuate.[151] An explosion then occurred while [redacted]

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135 Wisconsin Department of Justice DCI Interview of [redacted]. June 28, 2017. p. 3. WDOJ_000489.

136 Wisconsin Department of Justice DCI Interview of [redacted]. June 14, 2017. p. 3. WDOJ_000380.

137 Deposition Transcript of [redacted], May 13, 2021. p. 139.

138 U.S. Chemical Safety and Hazard Investigations Board Interview of [redacted]. July 11, 2017. p. 8. GJ_CSB_0005689.

139 [redacted] Employee Interview Statement to OSHA. July 20, 2017. p. 3. DM0004499.

140 Deposition Transcript of [redacted], May 13, 2021. p. 136.

141 Wisconsin Department of Justice DCI Interview of [redacted]. June 28, 2017. p. 3. WDOJ_000489.

142 U.S. Chemical Safety and Hazard Investigations Board Interview of [redacted]. July 11, 2017. p. 9. GJ_CSB_0005690.

143 [redacted] Interview Statement to OSHA with Translation. August 28, 2017. p. 9. DM0004421.

144 U.S. Chemical Safety and Hazard Investigations Board Interview of [redacted]. July 11, 2017. pp. 49-50. GJ_CSB_0005730-1; Deposition Transcript of [redacted] May 13, 2021. p. 136-137.

145 Deposition Transcript of [redacted], May 24, 2021. pp. 14, 17.

146 Deposition Transcript of [redacted], May 13, 2021. p. 141.

147 Deposition Transcript of [redacted], May 13, 2021. pp. 141-142, 147-148.

148 [redacted] heard Mr. Nunez speaking in Spanish at the time but did not understand. [redacted] testified that he later understood the intent of Mr. Nunez's words upon speaking with colleagues after the incident occurred.

149 Deposition Transcript of [redacted], May 13, 2021. pp. 152-155.

150 Deposition Transcript of [redacted], May 13, 2021. pp. 152-153, 157-158.

151 U.S. Chemical Safety and Hazard Investigations Board Interview of [redacted]. July 11, 2017. p. 10. GJ_CSB_0005691.

[redacted] was under Bin 26.[152] This occurred some number of seconds after he had exited B1;[153] [redacted] believes that this explosion occurred in B1.[154] The heavy steel roll-up garage door near the B1 door reportedly blew off past [redacted], and smoke and flame rushed out.

He continued to quickly exit the facility (Blue line connecting Locations 3 and 4; Figure 24). As [redacted] reaches Location 4 in Figure 24, which he estimated to be about three to five seconds after the B1 explosion, the Dry Grit Filter above him blew up and knocked him into the east wall of the D-Mill and to the ground.[155,156,157] At this point, [redacted] estimated that about 15 to 20 seconds had elapsed since he exited B1.[158] [redacted] continued to run toward the parking lot and then on toward Location 5; Figure 24.[159,160] He recounted feeling the rumbles of three additional explosions during this time.[161] By the time [redacted] reached the truck scale, another explosion occurred. This explosion featured a fireball as tall as a silo. Closer to the time of incident, [redacted] believed that this explosion occurred in the center of the mill, potentially where the mill office / control room was located;[162] he later indicated that he believed it originated from a tank on a fork lift located within the Pack area.[163] [redacted] recalled one additional smaller explosion occurring after this. During different interviews, [redacted] has recounted in the range of seven to over ten explosions.[164,165]

2.6.4.2 Status of [redacted] after the Initial Events of B1

[redacted] exited the way that he entered, which was up the staircase to the mill office (Top left corner of B-Area in Figure 24).[166] [redacted] passed Mr. Block as he traveled to the mill office and told him that the Baumeister "was exploding."[167] The first explosion occurred by the time

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[152] Deposition Transcript of [redacted], May 13, 2021. pp. 141-142, 147-148.

[153] U.S. Chemical Safety and Hazard Investigations Board Interview of [redacted]. July 11, 2017. p. 44. GJ_CSB_0005725.

[154] Deposition Transcript of [redacted], May 13, 2021. pp. 143-145.

[155] Note: The Dry Grit Filter is at times also referred to as a Drager filter.

[156] Deposition Transcript of [redacted], May 13, 2021. pp. 146-147.

[157] U.S. Chemical Safety and Hazard Investigations Board Interview of [redacted]. July 11, 2017. p. 11. GJ_CSB_0005692.

[158] Deposition Transcript of [redacted], May 13, 2021. p. 148.

[159] U.S. Chemical Safety and Hazard Investigations Board Interview of [redacted]. July 11, 2017. p. 13. GJ_CSB_0005694.

[160] Deposition Transcript of [redacted], May 13, 2021. pp. 155-156.

[161] Deposition Transcript of [redacted], May 13, 2021. pp. 167-168.

[162] U.S. Chemical Safety and Hazard Investigations Board Interview of [redacted]. July 11, 2017. p. 15. GJ_CSB_0005696.

[163] Deposition Transcript of [redacted], May 13, 2021. pp. 169-170.

[164] Deposition Transcript of [redacted], May 13, 2021. p. 167.

[165] U.S. Chemical Safety and Hazard Investigations Board Interview of [redacted]. July 11, 2017. p. 13. GJ_CSB_0005694.

[166] Deposition Transcript of [redacted], May 13, 2021. pp. 140-141.

[167] [redacted] Interview Statement to OSHA with Translation. August 28, 2017. p. 10. DM0004422.

[redacted] reached the staircase between the floors for A2 and B2, about 15 to 20 seconds after the communication with [redacted] about exiting B1.[168,169] He heard several explosions by the time he arrived at B2. Upon arrival at B2, he opened the door and observed fire that appeared to be coming from B1. He then closed the door and turned around to travel to the control room. A series of additional "strong" explosions occurred, including a "very big explosion," after which the lights went out. [170,171] [redacted] was able to get out by the office, travel down the stairs, locate some co-workers, and exit the building. [redacted] estimated that around five explosions occurred in total.[172]

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[168] U.S. Chemical Safety and Hazard Investigations Board Interview of [redacted]. September 20, 2017. pp. 10-13. GJ_CSB_0004990-3.

[169] Deposition Transcript of [redacted], May 24, 2021. pp. 15-18.

[170] U.S. Chemical Safety and Hazard Investigations Board Interview of [redacted]. September 20, 2017. pp. 10-13. GJ_CSB_0004990-3.

[171] Deposition Transcript of [redacted] May 24, 2021. p. 94.

[172] Deposition Transcript of [redacted], May 24, 2021. p. 93.

3 Engineering Analysis

The following sections summarize my opinions and findings regarding the May 31, 2017, explosion at Didion Milling in Cambria, Wisconsin. The bases for each opinion are described in detail in the body of my report and/or contained within the materials reviewed in conjunction with my work on this matter.

I hold the following opinions to a reasonable degree of engineering and scientific certainty based on relevant literature and standards, common practices in the industry, and the materials that I have reviewed to date. I reserve the right to supplement this report and to expand or modify any opinions based on review of material as it becomes available through ongoing discovery and through any additional work.

3.1 Opinion 1: Origin of the Explosion

Opinion 1: *The explosion originated in the South Bauermeister (SBM) on the first floor of the B-Mill (B1). The explosion was preceded by an upset in the operation of the SBM.*

The data is consistent with ignition within the South Bauermeister, concurrent with an upset that resulted in a reduction of flow and increase in product temperature, but the precise cause of ignition mechanism is outside the scope of this analysis. Witness testimony is consistent that the first visible flame was seen exiting the SBM, and that the explosion followed thereafter (Section 2.6.4).[173,174] No evidence exists of visible smoke or flame exiting from any other equipment anywhere in the mill prior to the first flame exiting the SBM.

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[173] *See, e.g.,* Wisconsin Department of Justice DCI Interview of [redacted]. June 28, 2017. p. 3. WDOJ_000489. p. 3.

[174] For purposes of this report, specific issues of causation and initial ignition are not relevant, but Exponent reserves the right to opine on those issues in the future in this or other litigation as may be appropriate.

D16670 - 0183 (cropped)

Figure 25. South (left) and North (right) Bran Grinder Bauermeisters located in B1.

In addition to witness statements, process data are consistent with the explosion originating from the SBM under the following timeline:

- At 10:13 PM, the temperature measured within the South Bauermeister began to rise at a gradual rate, increasing by approximately 12°F over the next 30 minutes, from 170°F to 182°F.
- At 10:45 PM, the temperature plateaued at approximately 182°F for the next 6 minutes.
- At 10:51 PM, the temperature spiked relatively sharply, increasing by 11°F in the 2 minutes between 10:51 PM and 10:53 PM, from 182°F to 193°F.
- At 10:53 PM, the temperature rapidly decayed from 193°F to 186°F over the remaining 7 minutes prior to the explosion.
- Between 11:00 PM and 11:01 PM, the temperature rose from 186°F to a temperature over 209°F (over the scale of the recording).

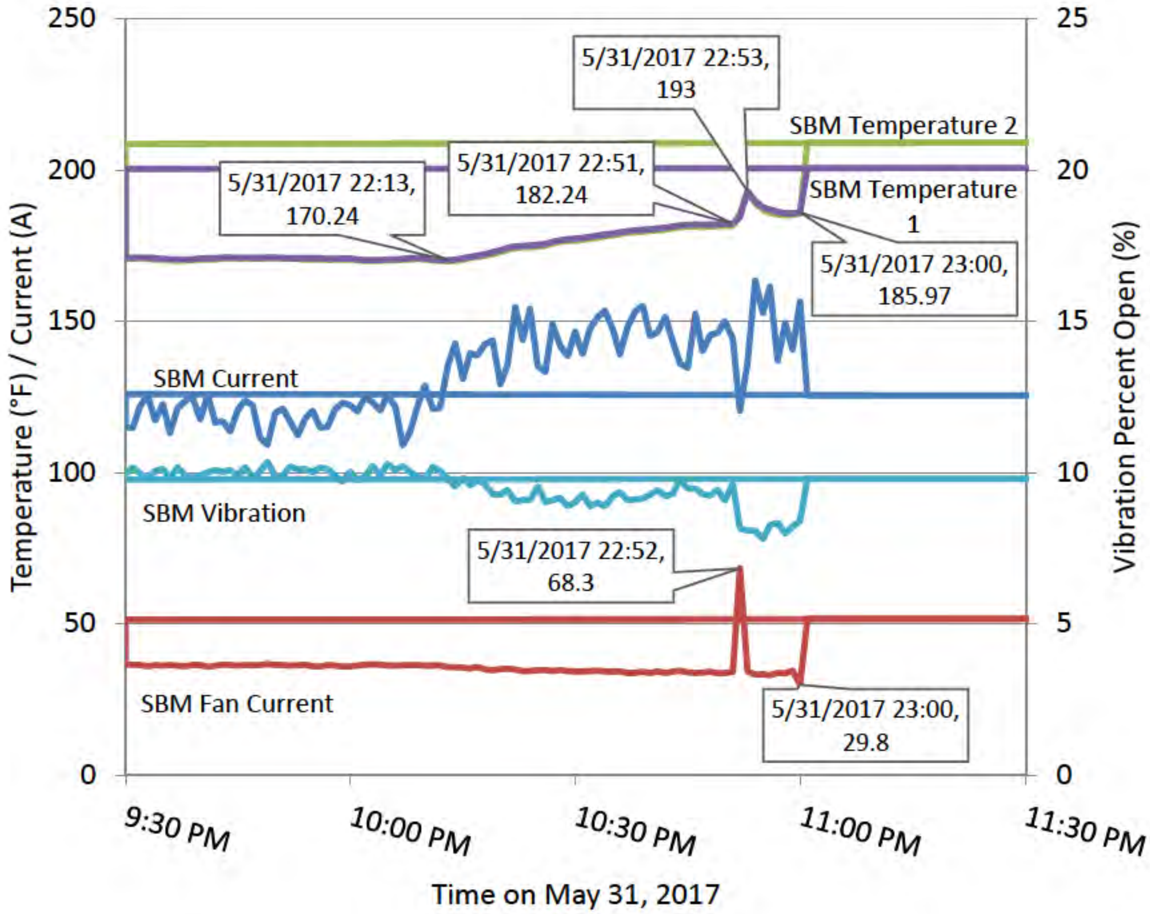

Figure 26. Temperatures, currents, and vibrations experienced by the South Bauermeister (SBM) on May 31, 2017.[175]

The data suggest that the discharge from the SBM was reduced, as indicated by the increase in SBM Fan Current at 10:52 PM. This represents a sudden increase in power required to maintain the same rotational speed, consistent with a sudden resistance to flow. After 10:52 PM, temperature quickly spiked from 182°F to 193°F, and then began to decline. The SBM motor current remained high, and the vibration measured on the equipment suddenly dropped to a lower value. The last data point recorded on the SBM Fan Current showed a sudden decrease. The behavior of the data is consistent with a sudden reduction in the resistance to flow, e.g., a quick surge of material.

The explosion occurred between the computer clock time 11:00 PM and 11:01 PM, as all relevant data went off-scale. Prior to the final reading after 11:00 PM, the temperature measurement never exceeded the high temperature alarm of 195°F.[176]

[175] DCS Data on May 31, 2017: SBM Temperature 1 (TT1-13030; DIDION0001619), SBM Temperature 2 (TT2-13030; DIDION0001626), SBM Current Amps (VFD-13030; DIDION0001709), SBM Vibration (VB-13030; DIDION0001663, DIDION0024370), SBM Fan Current (VFD-13034; DIDION0001711).

3.2 Opinion 2: Multiple Explosions (Deflagrations)

Opinion 2: *Multiple explosions (deflagrations) occurred within the Bran System, starting before the departure of witnesses from B1, as indicated by the flames described as extending from the air inlet duct that serves the discharge line of the SBM. Explosions propagated internally within process equipment and dust collection equipment located in B1 to equipment located throughout the facility, contributing to the magnitude and distribution of the damage and destruction observed after the incident.*

Witness observations of lingering smoke (Section 2.6.4) and a gradual rise in temperature within the SBM (Section 3.1) indicate that material was likely smoldering prior to the first explosion (deflagration). However, the first observed evidence of internal propagation within the SBM was the ejection of the suction line air-intake filter[177,178] and subsequent pressurized release of burning material into B1, as evidenced by the jet fire (flame) observed by [redacted][179,180] (refer to Section 2.6.4). In addition to these witness observations, the physical evidence shows that flames propagated *internally* to ducts and equipment located both downstream and upstream of the SBM.

In discussing this first flame, [redacted] noted that, after about five seconds, the flame "sucked back in" and disappeared.[181] Several seconds later, [redacted] observed the flame reappear.[182] These two direct observations of separate flames propagating from inside the South Bauermeister represent two internal propagation events that were directly observed within B1. Each time flaming material was discharged into B1 from the air inlet of the SBM was a direct result of an internal increase in pressure within process equipment, which ejected fuel and burning material.

Flame also ultimately propagated downstream of the SBM toward the Torit Filter. The Torit Filter was immediately downstream of the cyclones that separated bran from fines product coming out of the two Bauermeisters (Figure 15). No significant obstruction existed between the SBM and the Torit Filter, and it was observed that the two pieces of equipment in-between, the cyclone and the fan, were both damaged. The SBM Cyclone was damaged due to interior overpressure, and the fan downstream was damaged due to a combination of the effects of flame and overpressure. Each is discussed below in Section 0.

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[176] DIDION0024211.

[177] U.S. Chemical Safety and Hazard Investigations Board Interview of [redacted]. July 11, 2017. p. 8. GJ_CSB_0005689.

[178] Wisconsin Department of Justice DCI Interview of [redacted]. June 28, 2017. p. 3. WDOJ_000489.

[179] Wisconsin Department of Justice DCI Interview of [redacted] June 14, 2017. p. 3. WDOJ_000380.

[180] Deposition Transcript of Hayden Dodge, May 13, 2021. p. 139.

[181] U.S. Chemical Safety and Hazard Investigations Board Interview of [redacted]. July 11, 2017. p. 8. GJ_CSB_0005689.

[182] Wisconsin Department of Justice DCI Interview of [redacted]. June 28, 2017. p. 3. WDOJ_000489.

The equipment in the Bran System quickly became involved in the propagating explosion. Ducts in the Bran Process were separated during the explosion, potentially as early as the initial propagation events while [redacted] and others remained in B1. Evidence of propagation throughout the Bran System is shown and described in Section 3.2.1. The Torit Filter itself was not significantly damaged, but the header that feeds the Torit Filter ducting served as a conduit for flame to propagate throughout the facility. Connections in the Torit Filter header in both the A and B-Mills showed evidence of the pressurized release of burning material. Other equipment feeding the Torit Filter header exhibited similar damage. The propagation through the Torit Filter System is discussed further in Section 3.2.2.

Seconds after the explosion in B1, [redacted] reported an explosion within the Dry Grit Filter.[183,184] The Dry Grit Filter was fed by equipment throughout the mill. Due to the configuration of equipment and the timing of the event, the only viable explanation for the explosion in the Dry Grit Filter is that a flame must have spread internally throughout equipment and ducts within the mill from B1. This mechanism and the evidence of propagation through the Dry Grit Filter header and the connected process lines conveying combustible dust are discussed in Section 3.4.

The damage created by this process was likely exacerbated to varying degrees by flame acceleration and pressure piling, described above.[185] This phenomenon also likely contributed to the short timing between the explosions described by [redacted] when he was on the eastern exterior of the mill buildings, after the initial interior explosions that he observed venting from the equipment (Section 2.6.4.1).

The evidence described below demonstrates that process and dust conveying lines served as the primary pathway for propagation of pressure and flame from the SBM in B1 to locations elsewhere in the mill facility.

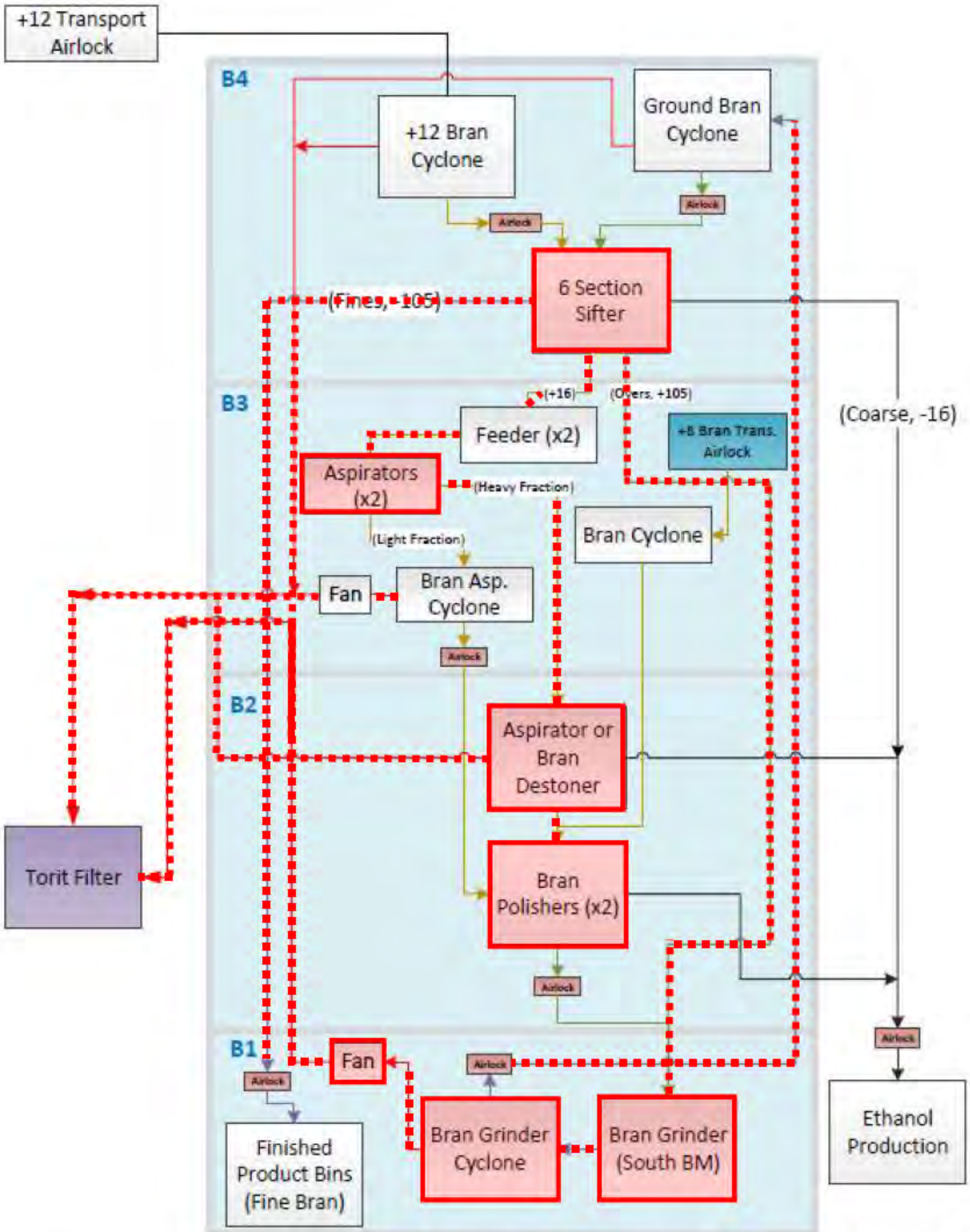
3.2.1 South Bauermeister (SBM) in B1 to Bran System (B-Mill) and Torit Filter

As described by the witness statements (refer to Section 2.6.4), an initial "boom" was heard, the air-intake suction line filter "blew off," and two separate instances of flame emerged out of the air-intake suction line. These first two flames represent the first observed propagation of the flame internally from the SBM. This section discusses additional evidence of internal flame propagation and overpressure experienced in the Bran System in the B-Mill. Damage consistent with internal propagation was observed throughout the B-Mill, including the propagation pathways highlighted in Figure 27.

183 Deposition Transcript of [redacted], May 13, 2021. pp. 146-147.

184 U.S. Chemical Safety and Hazard Investigations Board Interview of [redacted]. July 11, 2017. p. 11. GJ_CSB_0005692.

185 Ogle R. (2017). Dust explosion dynamics. Elsevier. § 9.4 Pressure Piling.



Adapted from Highlighted PFDs - Bran System.pdf and REF-MILL-ENG-4203-01 Bran System S#3.pdf

Figure 27. Damage observed though post-incident photo documentation in the Bran System in the B-Mill shown in red. Additional damage may have occurred in equipment that was not accessible and/or was damaged during demolition.

3.2.1.1 Damage observed in Bran System: B-Mill – 1st floor

As discussed above, the first observation of an explosion was from the air-intake suction line downstream of the SBM located on the first floor of the B-mill, referred to as “B1.” This piece of equipment was a part of the Bran System discussed in Section 2.5.2. As shown above in Figure 27, the SBM is fed by a line comprised of the +105 overs from the 6 section Bran Sifter on B4 and the two Bran Polishers on B2. The +8 Bran Cyclone on B3 fed the +8 North Bran Polisher on B2 with an optional line directly into the feed line for the SBM. At the time of the incident, the +8 Bran Cyclone was feeding the +8 North Bran Polisher on B2 (and not the SBM), as shown in the PFD in Figure 27. The output from the SBM supplies feed to the South Bran Grinder Cyclone, which has airflow from the South Bran Grinder Fan that goes directly into the Torit Filter header, the latter of which is discussed in further detail in Section 3.2.2.

For simplicity, the South Bran Grinder Cyclone and South Bran Grinder Fan, which are affiliated with the SBM, will be referred to here as the SBM Cyclone and SBM Fan, respectively. Similarly, the cyclone and fan downstream of the NBM will be referred to as the NBM Cyclone and NBM Fan, respectively. The bottoms of the SBM Cyclone are recycled to the top of B4 through the Secondary Flour Removal and Grinding subsystem of the Bran System.

Figure 28 shows the SBM after the incident. Photographic evidence shows that the explosion propagated from the SBM directly into the SBM Cyclone. Damage was also found to a lift line that transports material to the Ground Bran Cyclone on B4, evidence of propagation that could have occurred either through the Torit Filter header or through burning material in the ducting connecting B1 to B4.

D16670 - 0183

Figure 28. Post-incident view of South (left) and North (right) Bran Grinder Bauermeisters located in B1.

The SBM feeds directly into the SBM Cyclone (Figure 28). Heat damage to the SBM Cyclone is observed in Figure 29 through the discoloration on the top of the SBM Cyclone. The ducting at the top side of the SBM Cyclone is directly fed from the SBM.

Figure 29. Post-incident view of SBM Cyclone (left) and NBM Cyclone (right). A separation can be seen at the top of the SBM Cyclone.

Figure 30 and Figure 31 show evidence of an internal overpressure event as well as discoloration due to heat and flame effects. This overpressure resulted in separation at a connection near the top of the SBM Cyclone (Figure 30). The disparity in appearance between the BM Cyclones is consistent with increased heat exposure localized to the SBM Cyclone, from either a prolonged internal fire or a sustained flame emitting from the separation.

Figure 30. Top of SBM Cyclone duct that feeds into the SBM Fan post-incident. The separation occurred at the connection indicated by the yellow arrow as internal overpressure lifted the top of the SBM cyclone. This is unequivocal evidence of internal propagation downstream from the SBM.

As shown in Figure 27, the heavier material (sometimes called bottoms or heavies) discharged from the SBM and NBM Cyclones was recycled and sent to B4 to be processed through the 6-section filter and to travel through the Bran Process in the B-mill again. The fines from the top of the SBM and NBM Cyclones were fed into the SBM and NBM Fans, which were located on the B1 mezzanine shown in Figure 31.

D16682 - 0228 (top); D16682 – 0046 (bottom – left), D16682 – 0049 (bottom – right)

Figure 31. Post-incident view of NBM Fan (top left) and SBM Fan (top right) on the B1 mezzanine with zoomed in photos of the SBM Fan (bottom left and right).

Incontrovertible evidence of flame propagation through the SBM Fan is shown in Figure 31. The flexible connection between the SBM Fan and its inlet duct was destroyed during the event,

and signs of internal heat and flame can be seen inside and out. The output from the SBM Fan fed directly into the Torit Filter Header through a duct that traversed the first three floors of the B-mill before it exited and turned downward to the 2^{nd} floor of the F-Mill (F2), as discussed in Section 3.2.2.

3.2.1.2 Damage observed in Bran System: B-Mill – 4th floor

As shown above in Figure 27, the SBM is fed by a line comprised of the +105 overs from the 6 section Bran Sifter on B4 and the two Bran Polishers on B2. The process flow diagram demonstrates that flame/pressure had multiple pathways to propagate through the +105 overs line to the 6-section Bran Sifter on the 4th floor of the B-Mill from the SBM as well as though the bottoms of the SBM Cyclone in B1. Photographic evidence demonstrates that such propagation reached the 6-Section Bran Sifter (Figure 32) as observed with the caps missing from the bottom ducts, suggesting that they were blown off due to internal overpressure.

D16682 - 0478

Figure 32. Post-incident view of 6-Section Bran Sifter on 4th floor of B-Mill (B4) with detached caps.

The 6-Section Bran Sifter on the 4th floor of the B-Mill is fed by the +12 Bran Cyclone, which is fed by ducting originating in D1[186,187] and the Ground Bran Cyclone, which is fed from bottoms of the SBM Cyclone in B1.[188] The 6-Section Bran Sifter feeds many of the pieces of equipment in the B-Mill discussed in the subsequent sections.

[186] REF-MILL-ENG-4202-01 Bran System S#2.pdf

[187] Highlighted PFDs - Bran System.pdf

[188] REF-MILL-ENG-4203-01 Bran System S#3.pdf

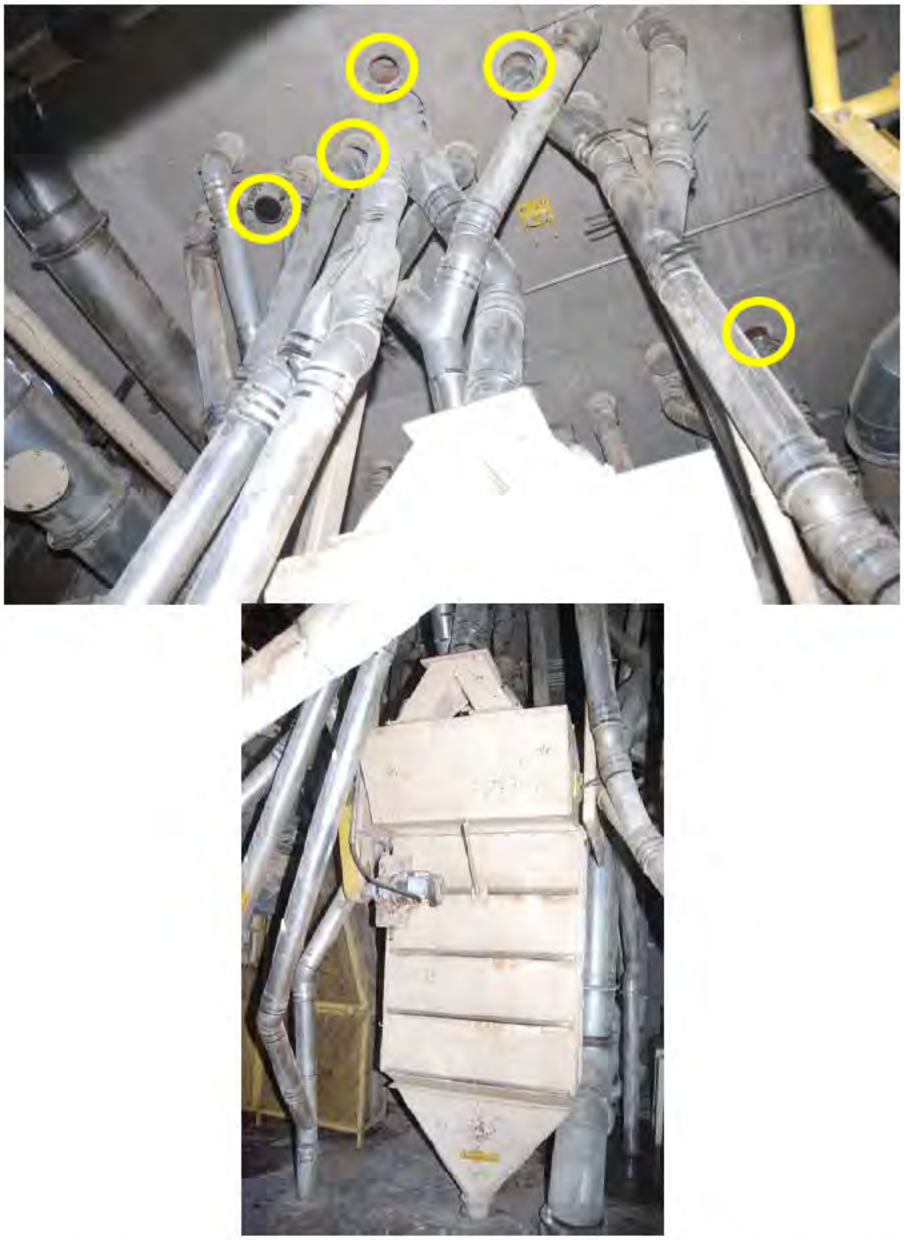
3.2.1.3 Damage observed in Bran System: B-Mill – 3rd floor

As shown in Figure 27, the 6-Section Bran Sifter feeds into multiple pieces of equipment on the 3rd floor of the B-Mill: 2 feeders, bran aspirator, and cyclones. The ducting from the bottom of the 6-Section Bran Sifter into the floor of B4 and ceiling of B3 is shown below in Figure 33.

D16682 - 0400 (bottom), D16682 - 0405 (top)

Figure 33. Post-incident view of ducting from 6-Section Bran Sifter that enters through the ceiling of B3 (top) and feeds into the North Bran Aspirator (bottom) (B3). Burn patterns on the ducting are consistent with the ejection of burning material from the location circled in red and the deposition of that burnt material on surfaces (circled in yellow) facing it.

As shown in Figure 33, the ducts connecting the North Bran Aspirator on B3 to the 6-section Bran Sifter on B4 were found disconnected. Note in the top image that there were clear burn patterns from the opening of the ducts and fuel splattering on adjacent piping through the duct opening. This burn pattern is indicative of an internal flame/deflagration source as compared to an external source. Note minimal, if any, fire damage was observed on the ceiling from B3 due to an external explosion.



D16686 - 00996 (bottom), D16686 - 00998 (top)

Figure 34. Post-incident view of South Bran Aspirator on the 3rd floor of the B-Mill (bottom). Disconnected ducts can be seen at the ceiling level (top)—these ducts carried the discharge from the 6-Section Bran Sifter.

Disconnected ducts were also observed above the South Bran Aspirator that fed into equipment on the 2nd floor of the B-Mill, shown in Figure 34. These disconnected ducts were immediately below the 6-Section Bran Sifter and are consistent with an internal overpressure event in multiple sections of this equipment.

The North and South Aspirators on the 3rd floor of the B-Mill were directly connected to the Torit System (Figure 35). The Torit Filter Header connects multiple pieces of equipment and

ducting on the 3rd and 2nd floor of the B-Mill. Evidence of flame and internal overpressure having propagated through the Torit Filter Header were observed in B3 and B2. Figure 35 shows the 36" Torit Filter Header in the center of the 3rd floor of B-Mill which contains 2 blinds: a 12" line and 20" line. No other PFDs for the facility have this combination of blinded lines. These two lines were photographed during the inspection after the incident and are shown below in Figure 36.

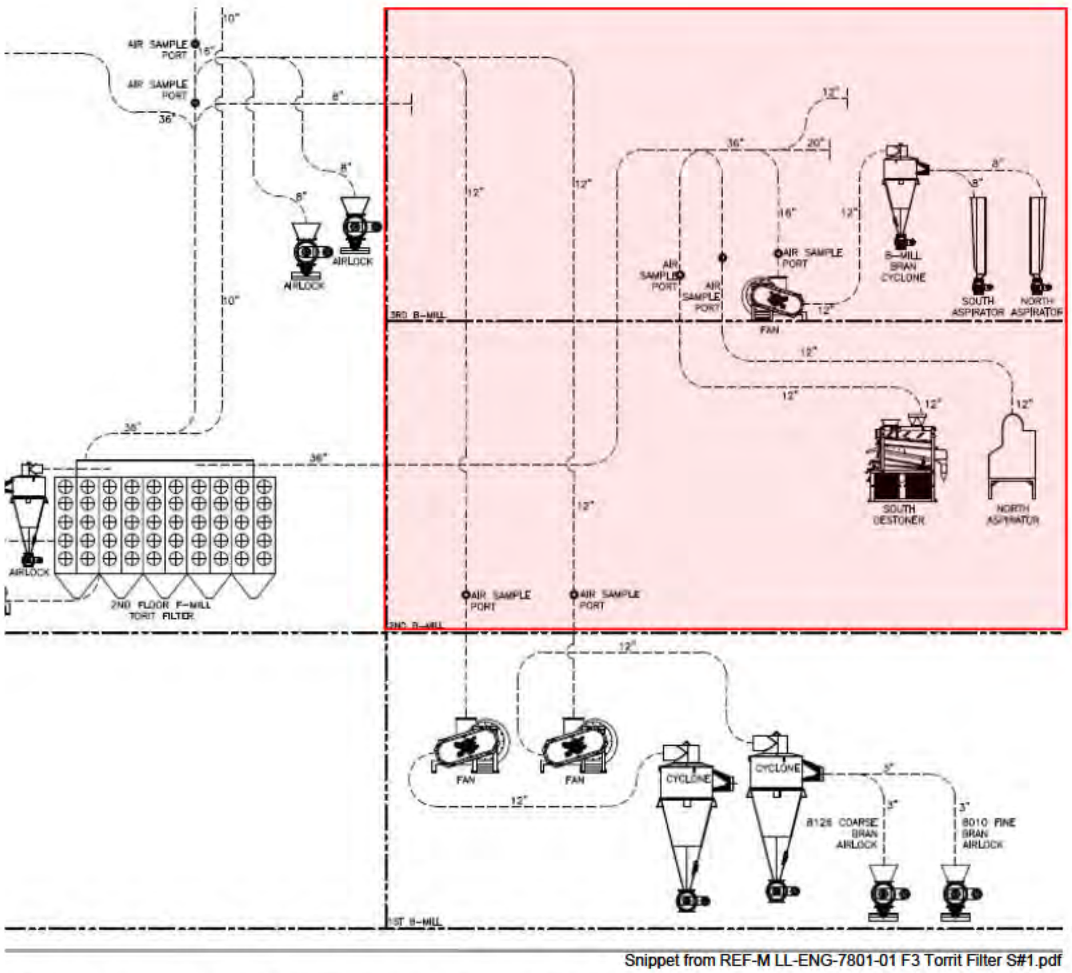


Figure 35. Torit Filter ducting in the B-Mill (1st, 2nd, and 3rd floor) with 2nd and 3rd floor highlighted in red.

D16686 - 00959 (top) D16686 - 00961 (bottom)

Figure 36. Post-incident view of 12" and 20" blinded lines that were connected to the 36" Torit Filter Header in B3 (top) and zoomed-in end of 36" line (bottom).

The top image in Figure 36 depicts both the 12" and 20" blinds. Remnants of burned, expelled product from the end of the 20" line were observed on surrounding walls and ceiling, which appear as scorch marks. A closer view of the scorch marks, shown in Figure 37, reveal the texture created by partially burned material that was ejected from the 36" duct. The 20" blind itself is observed to be deformed (Figure 36) from the overpressure experienced by the Torit Filter Header in B3.

D16686 – 00963 (top), D16686 - 00964 (bottom)

Figure 37. Close-up view of the apparent scorch marks in Figure 36 post-incident. The texture created by partially burned material ejected from the 36” Torit Filter Header (top) deposited on wires and other surfaces can be seen more clearly (bottom).

The 36" Torit Filter Header on the 3rd floor of the B-Mill has two 12" lines that feed the South Destoner and North Aspirator on the 2nd floor of the B-Mill (Figure 35). These lines are shown in Figure 38.

D16686 - 00990 (top) D16686 - 00992 (bottom)

Figure 38. Post-incident view of a flanged connection on B3 on a line that connects the Torit header on B3 and the South Destoner on the B2.

From Figure 38, an overpressure event inside the ducting resulted in deformed metal at the flanges connecting the ducting. This is consistent with the overpressure and burn patterns observed in Figure 36 for the 12" and 20" blinded lines connected to the 36" Torit Filter Header.

In addition to the equipment and ducting on the 3rd floor of the B-Mill, Exponent has documented evidence consistent with internal propagation through the pneumatic conveying line ("Blow Line") leading from the SBM Cyclone discharge to the Ground Bran Cyclone on B4. As seen in Figure 39, the SBM blow line is fully separated from the floor on B3. This separation is consistent with an internal overpressure event that occurred in the SBM line with flame/deflagration propagation through the lines.

D16680 - 0749

Figure 39. Post-incident view of ducting to SBM Blow Line (left) and the NBM blow line (right), which transport product from B1 to B4.

Additional ducts connected equipment between B1 and B4. An example of one of these lines is the 8010 Fine Bran Line (Figure 40). The detached cap is consistent with an internal overpressure event.

D16680 - 0836

Figure 40. Post-incident view of 8010 Fine Bran Line on the 3rd floor of the B-Mill with detached cap.

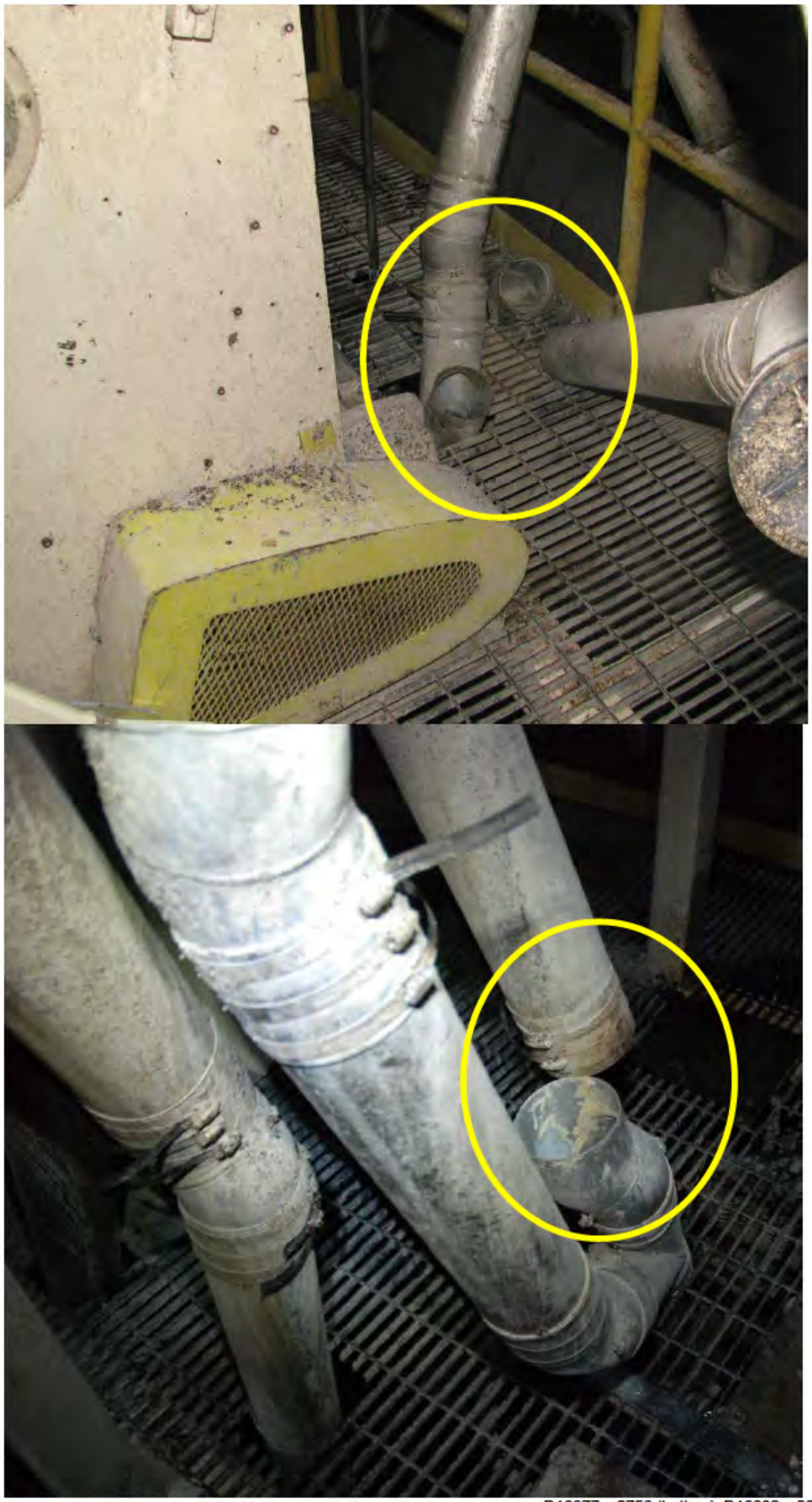
3.2.1.4 Damage observed in Bran System: B-Mill – 2nd floor

The equipment on the 2nd floor of the B-Mill is fed by both upstream ducts and/or connected to the Torit Filter Header (Figure 27). As shown in Figure 38, an overpressure event inside the ducting connecting the Torit Header line to the Bran Destoner on the 2nd floor of the B-Mill had deformed metal at the flanges connecting the ducting. Directly downstream of the Bran Destoner are the Bran Polishers shown in Figure 41, Figure 42, and Figure 43.

D16680 - 0620

Figure 41. Post-incident view of both North and South Bran Polishers located on the 2nd floor of the B-Mill (B2).

While it is difficult to see an overpressure event or burn patterns on the inside of the Bran polishers, evidence of internal overpressure events was observed on ducting connected to the Bran Polishers (Figure 42).



D16677 – 0756 (bottom), D16682 – 0274 (top)

Figure 42. Post-incident view of separated ducts both to the South Bran Polisher (top) and to the North Bran Polisher (bottom).

Figure 43 shows burned product sprayed onto both the Bran Polisher and the mezzanine support structure. The pattern of burned product indicates that product was sprayed internally from separated duct. The burn pattern is not consistent with an external flash fire (or explosion) fueled by widespread fugitive dust deposits, which would have resulted in a more uniform burn pattern.

D16680 - 0637 (top) D16682 - 0310 (bottom)

Figure 43. Post-incident view of splatter on Bran Polisher (top) and mezzanine support structure (bottom) from product ejected from separated ducts due to internal overpressure.

3.2.2 Torit Filter (F2) to rest of Mill (A-Mill, B-Mill, and F-Mill)

The outlet of the SBM Fan feeds directly into the Torit Filter Header through ducting that passes through B1, B2, B3, and F2 (Figure 44). A simplified PFD of the Torit System to other areas of the mill is shown below in Figure 45 and supported with photographs collected during multiple inspections.

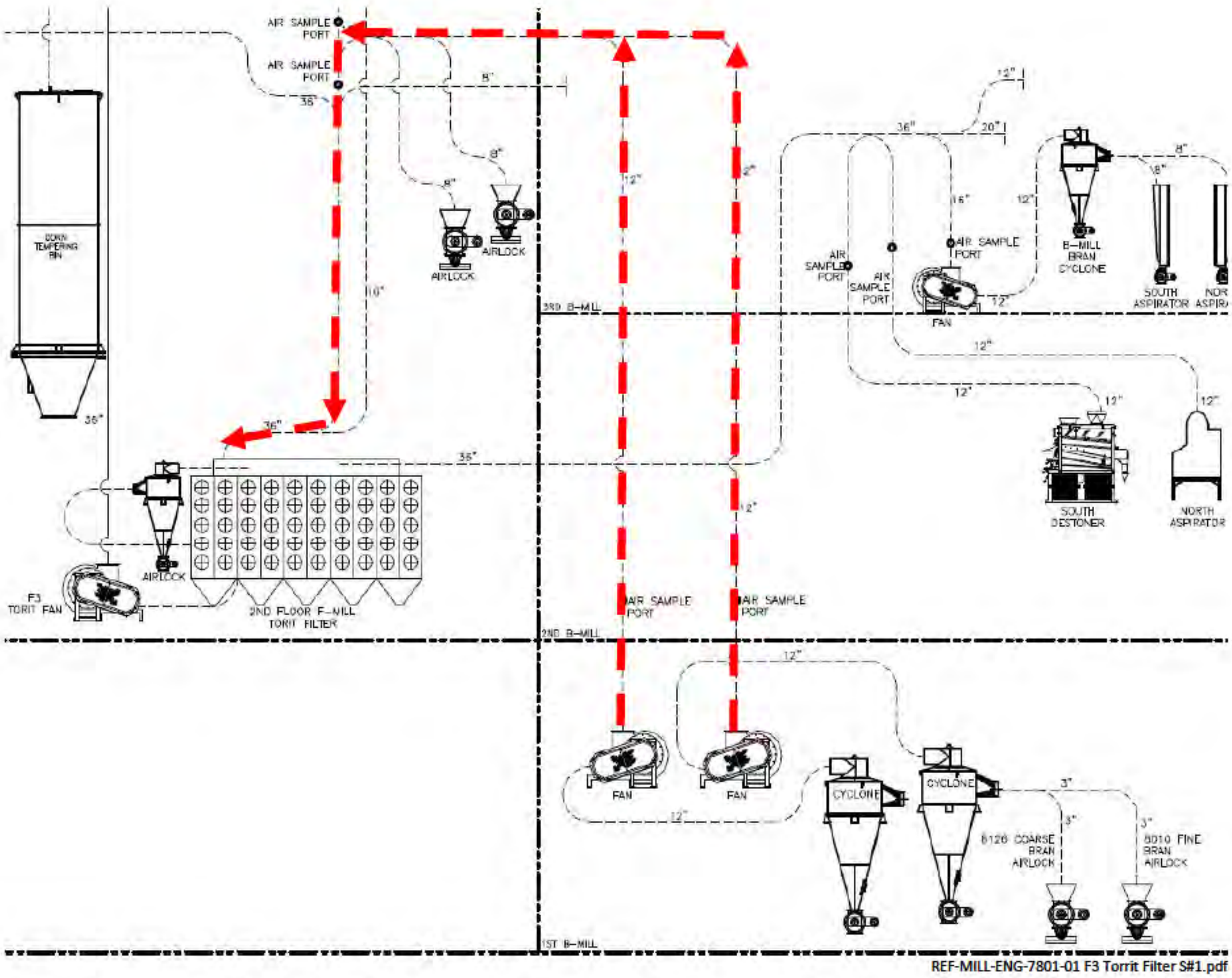
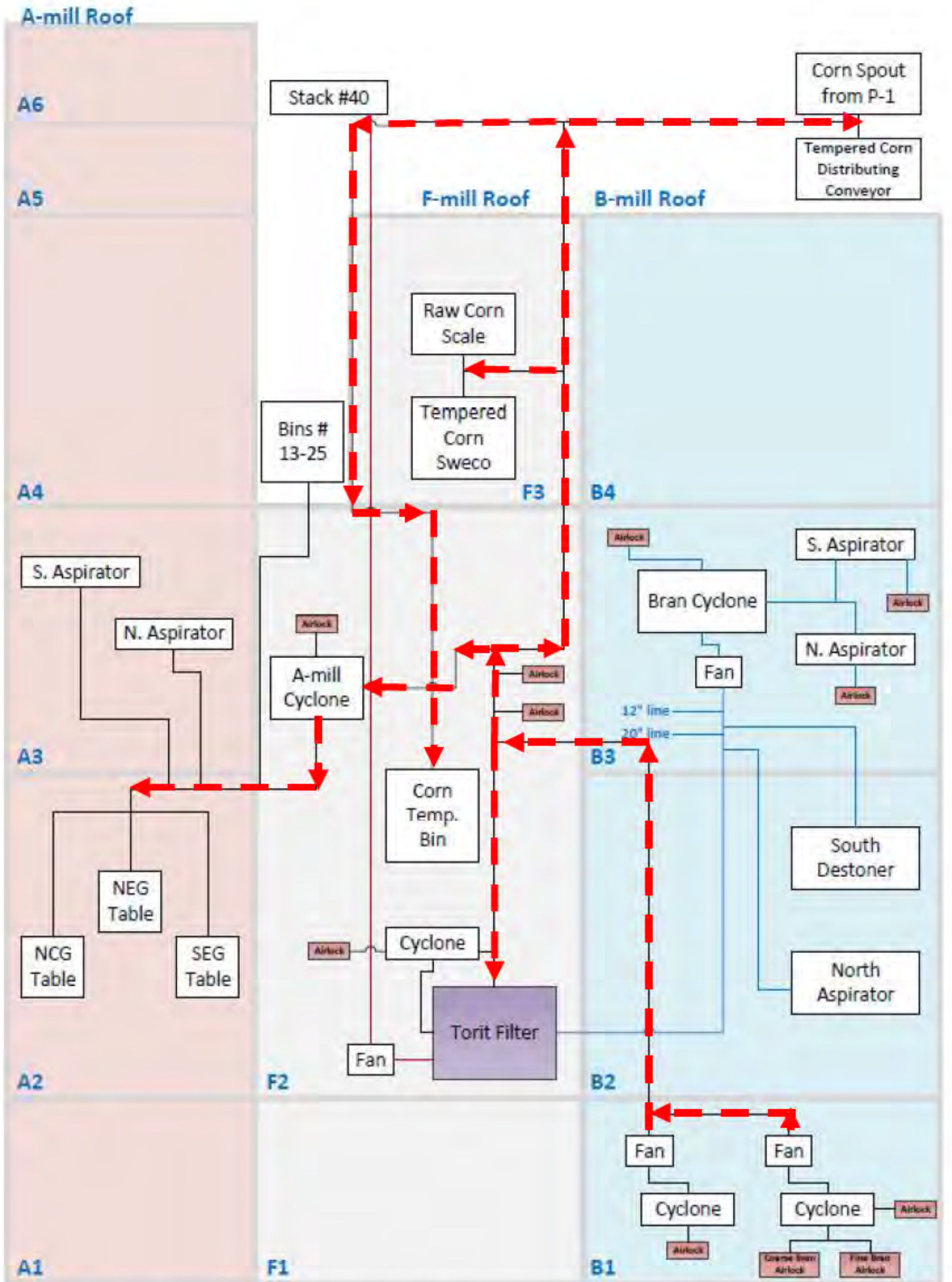


Figure 44. PFD of ducting from Bran Grinder Cyclones to Bran Grinder Fans to ducting into the Torit Filter (located on the 2nd floor of the F-Mill) with propagation pathways shown in red.



Adapted from REF-M LL-ENG-7801-01 F3 Torit Filter S#1 pdf

Figure 45. PFD of Torit System in B-Mill, A-Mill, and F-Mill with propagation pathways shown in red.

3.2.2.1 Torit System to F-Mill

The Torit Filter was located on the 2nd floor of the F-Mill (F2).[189] Although access to the remnants of the F-Mill post-incident was restricted for safety reasons, the Torit Filter was identified through photography and drone footage and was ultimately recovered. The Torit Filter itself can be seen as the large blue piece of equipment label "Torit Downflo" in Figure 47. The 36" header into the Torit Filter is detached but can be seen protruding from wall of the 3rd floor of the B-Mill in Figure 46.

[189] REF-MILL-ENG-7801-01 F3 Torrit Filter S#1.pdf.

D16649 - 0033

Figure 46. Post-incident view of duct (see yellow arrow) protruding from the 3rd floor of the B-Mill into the blue Torit Filter (located on what used to be the 2nd floor of the F-Mill).

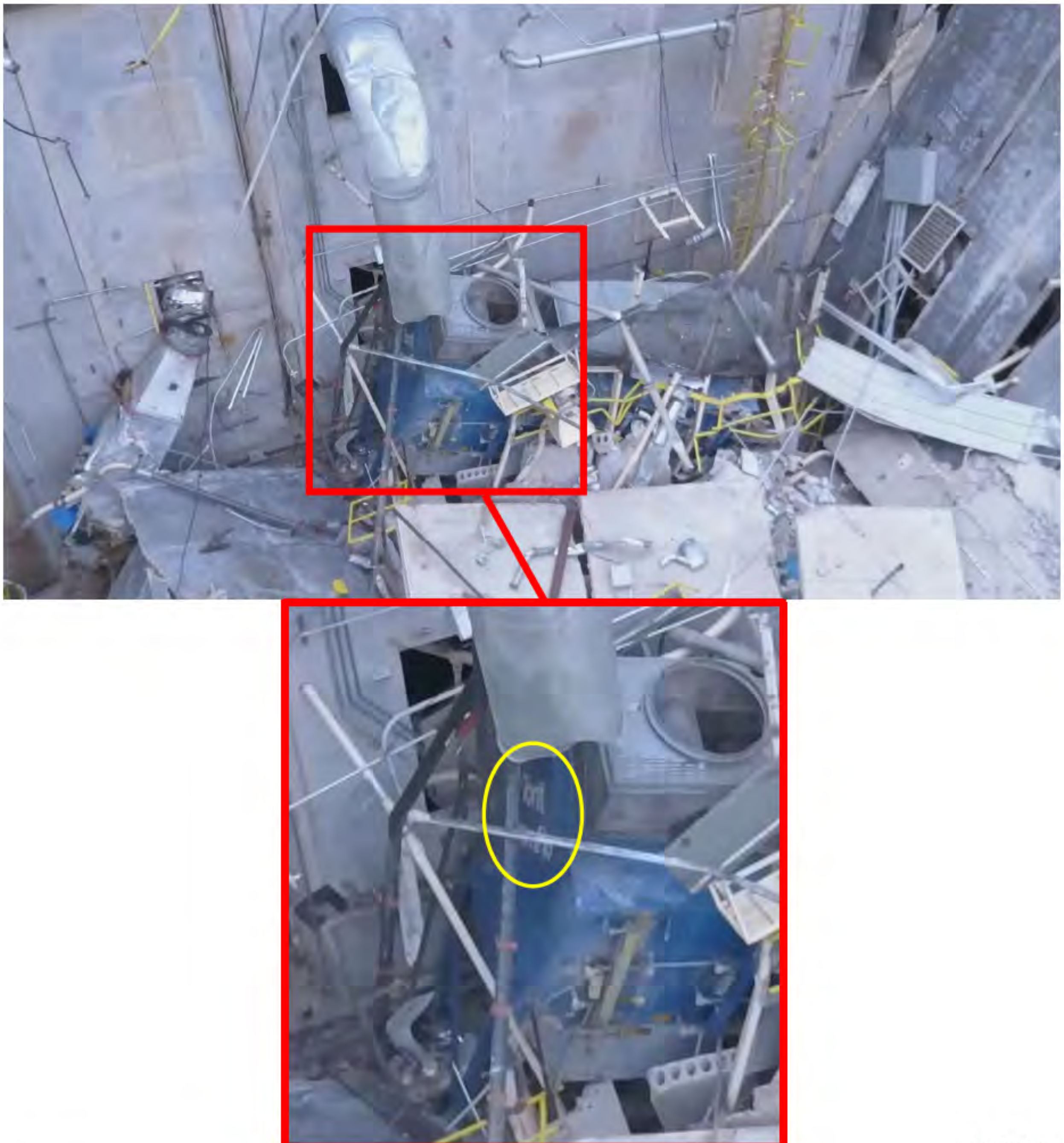


Figure 47. Post-incident aerial view of Torit Filter.[190]

Although the Torit Filter was readily identifiable, other equipment could not easily be identified in the aftermath of the incident. The Torit System PFD (Figure 45) shows that the Torit Filter

[190] Still of June 8, 2017, drone footage at 1:50. DJI_0005.MOV.

connects directly to the Corn Tempering Bin, A-Mill Cyclone (M-11517), Bins #13-25, Tempered Corn Sweco, and Raw Corn Scale. This equipment in the F-Mill is connected via ducting to other pieces of equipment such as multiple corn conveyors, mill corn chute, raw corn cleaning scalper, ethanol collection system, BMG filter, raw corn surge bin, and other equipment throughout the Mill.[191,192] Together, this is referred to as the Torit System or Torit Filter System.

3.2.2.2 Torit System to B-Mill

The Torit system is connected in the B-Mill through two different duct systems. The first system connects the North and South Bauermeisters, Cyclones, and Fans (Section 0 discusses propagation from the SBM in B1 to the Torit Filter in F2 and Section 3.2.1.3 discusses propagation from equipment on B3 to the Torit Filter). Engineering drawings do not identify any other connections between the Torit system and the B-Mill. The combination of witness statements about the first two flames observed in B1 (Section 2.6.4), the overpressure events associated with those two flames, and photographic evidence of internal propagation supports the hypothesis that the explosions in B1 propagated internally from the SBM through the Torit header ducts to the Torit filter. Note that the overpressure event did not propagate through the Torit filter itself but rather through the header ducts, although some limited quantity of oxidized, potentially burned material was found within the Torit.[193]

3.2.2.3 Torit System to A-Mill

At the time of the incident, the 36” Torit Filter lines and branches into the A-Mill contained multiple blinds where previous equipment was connected, e.g., three gravity tables that had been removed (Figure 45).[194] An example of a blind duct on the 2nd floor of the A-Mill is shown below in Figure 48.

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[191] Highlighted PFDs - Fractionation.pdf.

[192] REF-MILL-ENG-3001-01Corn Cleaning System S#1.pdf.

[193] E.g., see D16927 – 03991, D16927 – 04010, and D16927 - 04019.

[194] DIDION0073873.

Figure 48. Post-incident view of blind duct on second floor of A-Mill (A2) found open after the incident.

Figure 48 provides evidence that the blind was blown off, with soot deposition observed directly in front on the support member facing the opening. This evidence supports the hypothesis of internal propagation from the SBM in B1 to the Torit Filter header, which then internally propagated into the ducting on the 2nd floor of the A-Mill.

3.3 Opinion 3: Ejected Material Fueled Additional Explosions

Opinion 3: *As a result of the internal propagation of explosions through ducts and equipment, material was ejected at high velocity and concentration from multiple process and dust collection sources during the incident, including from equipment, separated ducts, and flanges. These ejections created explosive mixtures in air, several of which ignited. An explosion within the room B1 followed the initial internal explosions within the Bran System. In-process material ejected during the event provided adequate fuel to explain the damage observed in B1.*

Material was released at multiple locations throughout the progression of the incident. Ignition occurred in many of these release events, creating an expanding pressure wave and projecting flaming dust outward from the epicenter. The damage associated with such events can be seen throughout the facility, as documented extensively by Exponent through multiple inspections of the facility (discussed below). The contribution of the overpressure provided by each individual

release to the overall progression of flame and damage throughout the facility depends upon the timing of the ignition event or multiple ignition events.

The multiple explosions described by witnesses (Section 2.6.4) are consistent with these events distributed throughout the facility. Drone footage also shows excessive mill product ejected from separated ducts contributing to the open fuel source in the Mill.

3.3.1 Material Ejected in B-Mill

3.3.1.1 1st floor of B-Mill (B1)

Several notable sources of ejected material from equipment, separated ducts, and/or flanges were identified within B1. Flaming material was ejected from the air-intake suction line on the SBM in the form of the flames observed by witnesses. Additional material may have been ejected from the inlet to the SBM as the explosion progressed. The feed line to the NBM was displaced, which likely resulted in the ejection and suspension of flammable product around the NBM, shown below in Figure 49. Several other ducts were separated within B1. An explosion within the B1 room followed the initial internal explosions within the Bran System.

In-process material ejected during the event provided adequate fuel to explain the damage observed in B1 (as discussed and modeled in Appendix D). According to the mill PFDs, the design feed rate to the recycle loop containing the BMs was approximately 152 lbs/min (69 kg/min).[195] However, some of this material was separated before BMs, and so this is likely an overestimate of the anticipated flowrate through the BMs on the evening of May 31, 2017. During the first shift, the production rate was 24 lbs/min (11 kg/min).[196] However, the yield of product from the SBM was not 100%, i.e., a portion of the discharge was sent to EtOH feed and another portion was recycled to the 6-Section Bran Sifter. Thus, the steady state flow through the SBM is somewhere between 24 lbs/min and 152 lbs/min. This analysis is discussed in more detail in the context of the modeling described in Appendix D.

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[195] REF-MILL-ENG-4202-01 Bran System S#2.

[196] DIDION0001876 and DIDION0001877. 8.08 tons of Bran generated in 11 hours of uptime is 24 lbs/min.

D16677 – 0244 (left) D16680 – 0041 (right)

Figure 49. Post-incident view of North Bauermeister (left) with zoomed in image of severed inlet ducting (right).

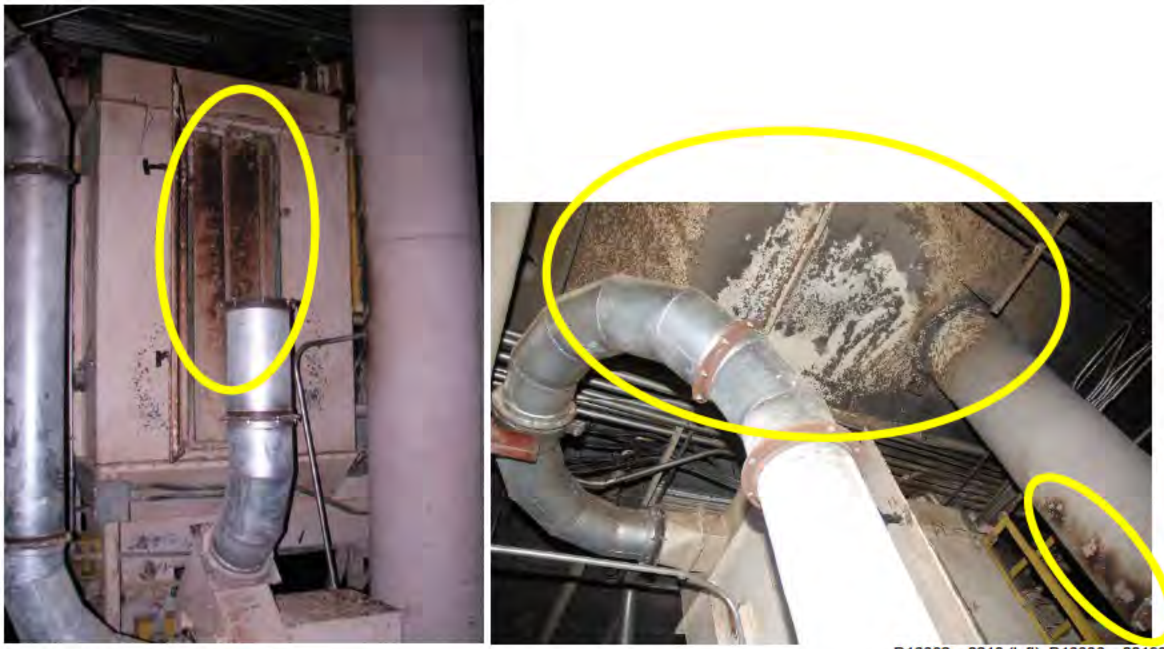
Extensive evidence of combustion around the separation in the inlet duct to the North Bauermeister is observed (Figure 49). This evidence is consistent with an overpressure in the feed line to the NBM resulting in displacement and ejection/suspension of flammable product around the NBM. Additional pieces of equipment on the 1st floor of the B-Mill show evidence of internal overpressure with burn patterns observed. The SBM fan on the Mezzanine in B1 is one such example (Figure 50).

D16680 – 0296 (left); D16682 – 0049 (right)

Figure 50. Post-incident view of SBM Fan on Mezzanine in B1 with zoomed in photo showing separated duct and clear soot deposition.

Incontrovertible evidence of flame propagation through the SBM Fan is shown in Figure 50. The flexible connection between the SBM Fan and its inlet duct was destroyed during the event, and signs of internal heat and flame can be seen inside and out. As discussed in Opinion 2, the flame propagated through the SBM fan into the Torit system, which is evident by section 3.2.

The Coarse Grinder Filter and surrounding areas in B1 also exhibited notable burn patterns, shown below in Figure 51. The Coarse Grinder Filter in B1 was open at the time of the explosion, and some material from inside the filter participated in the event. This is evidenced by the charring seen on the filter socks and on the column across from the filter. Material further inside the filter did not exhibit charring. Figure 51 shows evidence of burning material being ejected from the opened duct in front of the Coarse Grinder Filter on other equipment (left) and the ceiling (right).



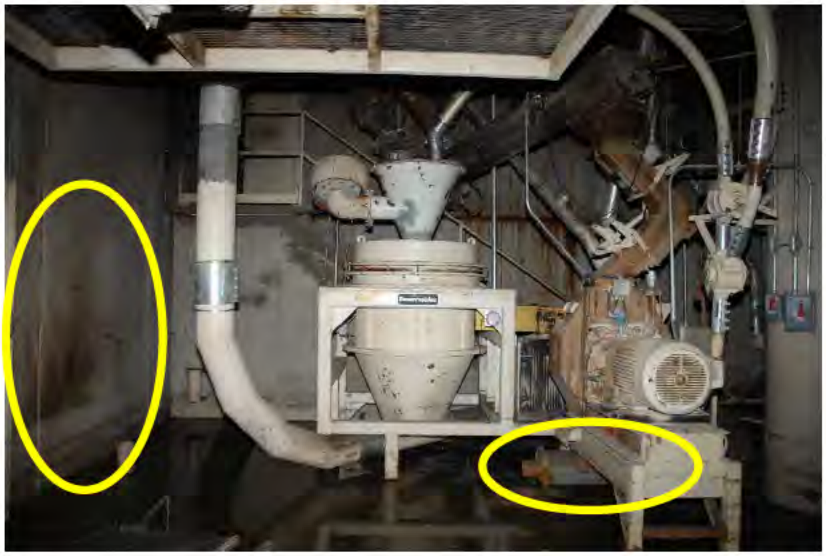
D16682 – 0218 (left), D16686 – 00198 (right)

Figure 51. Evidence of burning material being ejected from the duct in front of the Coarse Grinder Filter on other equipment (left) and the ceiling (right) in post-incident images.

Additional separated ducting is shown below in Figure 52. The separated spouts were connected to an inlet line to the Feed airlock. Additional splatter from projected fuel (mill product) onto the wall of B1 can be observed in Figure 53 from the Pregel Hammermill/Bauermeister intake line.

D16682 – 0131 (top, left), D16682 - 0156 (top, right; cropped) D16677 – 0323 (bottom, left), D16677 – 0324 (bottom, right)

Figure 52. Post-incident view of separated spout associated with an inlet to the Feed airlock, both located behind the SBM and NBM (seen in the foreground).



D16677 - 0106

Figure 53. Post-incident view of splatter on the wall (left) and the Pregel Hammermill/Bauermeister intake line (right).

3.3.1.2 2nd floor of B-Mill (B2)

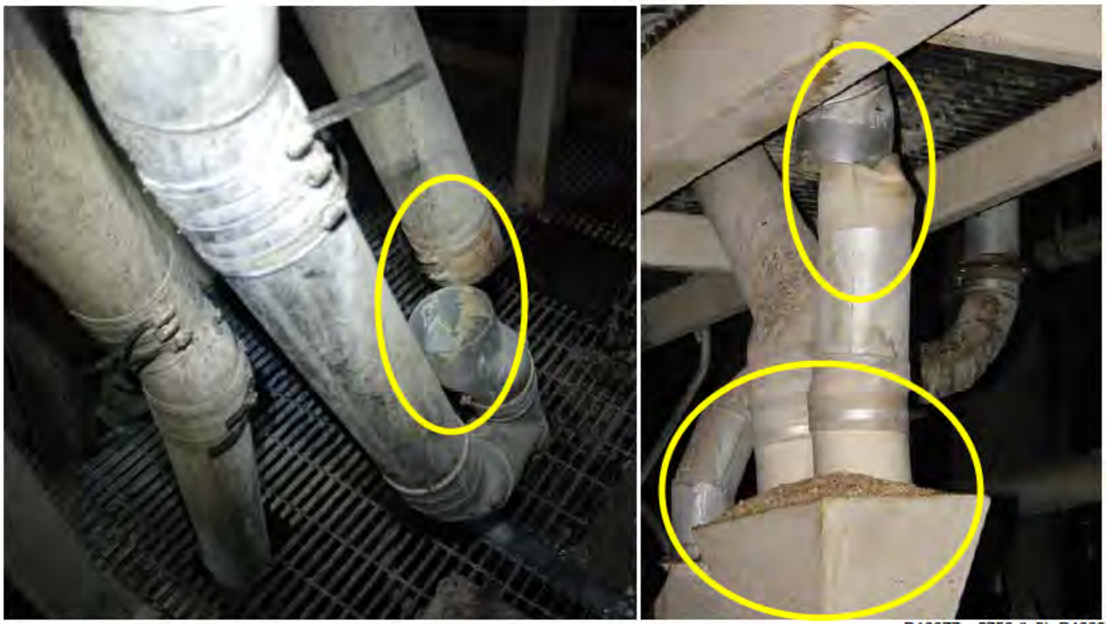
As described in Section 3.2, the explosion propagated internally through the ducting and equipment across the mill. Additional open pipes with evidence of burned material as a result of product ejected from internal ducts is shown below in Figure 54. Figure 55 depicts the separated duct between Expander 1 and the Expander 1 Solidaire. Deposits of burned material ejected from the separated duct can be seen on adjacent piping.

Figure 54. Post-incident view of burned material released from separated and/or blown-open pipes on 2nd floor of B-Mill.

Figure 55. Post-incident view of separated duct between Expander 1 and the Expander 1 Solidaire near the ceiling of 2nd floor of B-Mill (right) ejected burned product horizontally (left).

As overpressure and other forces associated with the explosion resulted in openings in equipment and ducts, fuel (e.g., process bran material) was sprayed through the opening onto other pieces of equipment. On some occasions, the material appears to have been ejected as it

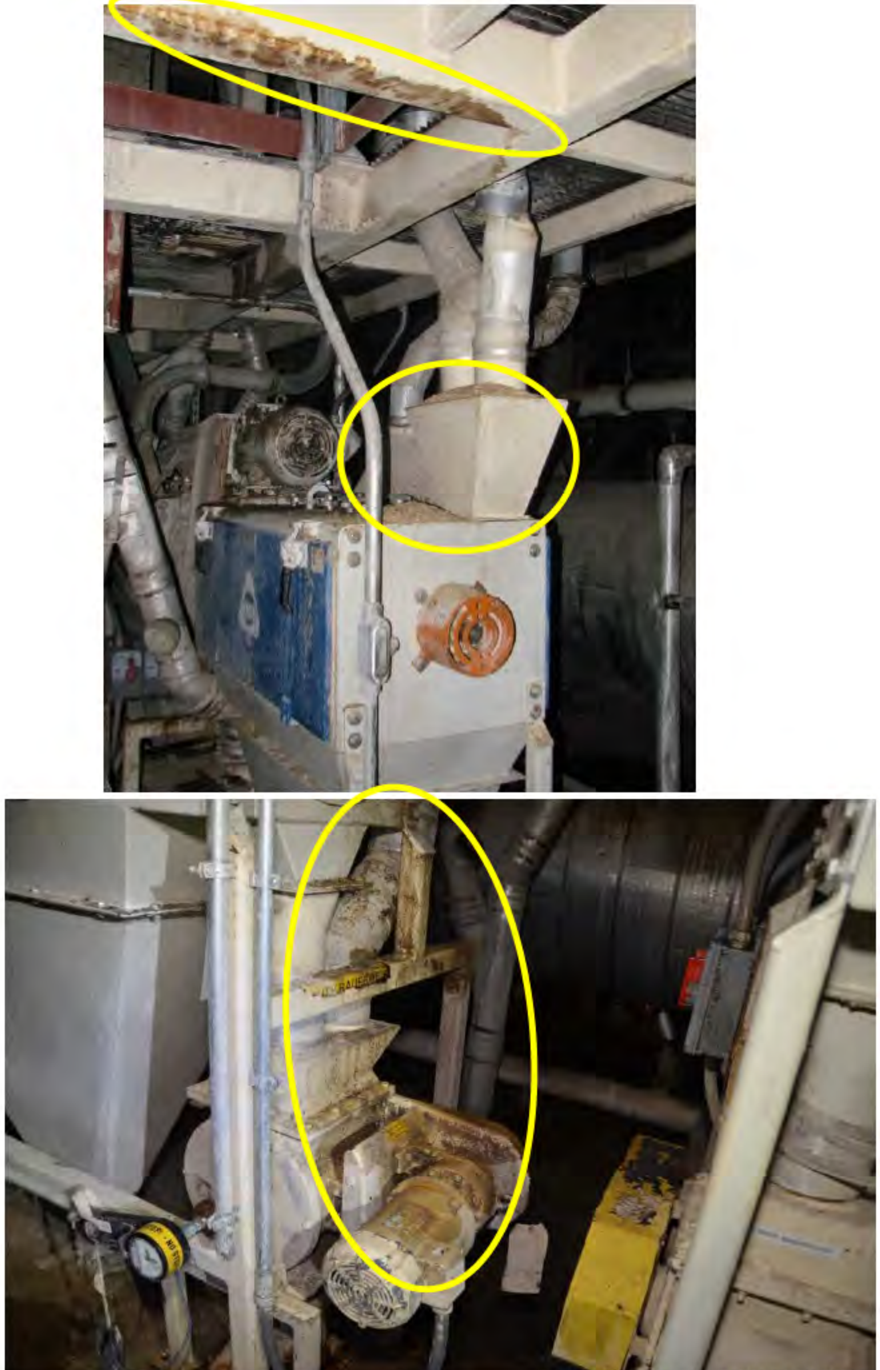
was burning, e.g., in Figure 55. Other material appears to have ignited after it was ejected, as observed in Figure 56 and Figure 57.



D16677 – 0756 (left), D16682 – 0311 (right)

Figure 56. Post-incident view of separated ducts associated with the North Bran Polisher (left) and South Bran Polisher (right) immediately upstream of the South Bauermeister.

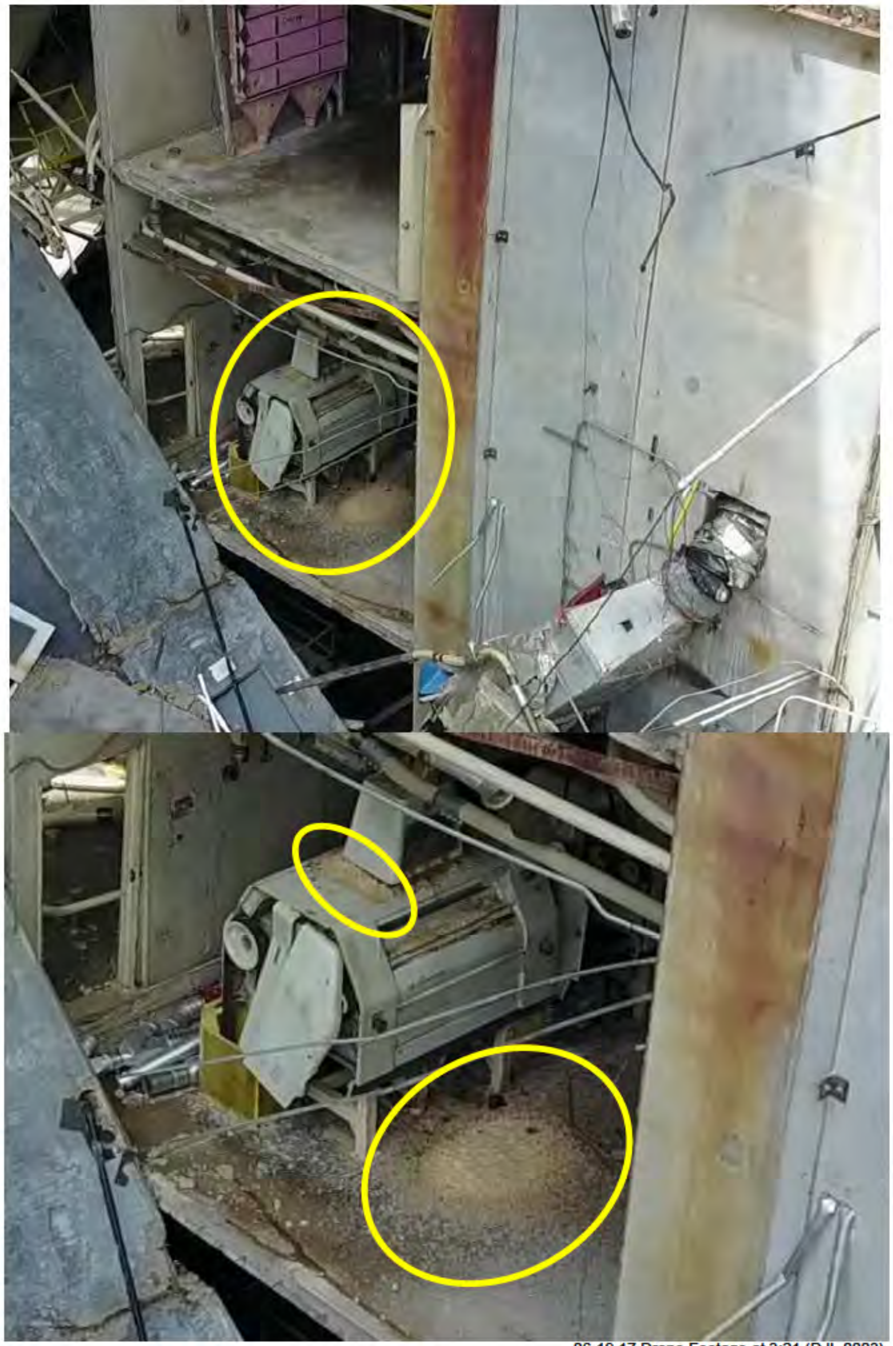
Product ejected from the feeds to the North Bran Polisher and the South Bran Polisher is shown in the same figure (Figure 56). Some material is seen piled on the South Bran Polisher, whereas some material clearly ignited and left behind partially burnt material (splatter) on the frame to the mezzanine and on the Bran Polisher ducting. Additional photos of the splatter on the Bran Polisher and support structures are shown below in Figure 57.



D16680 - 0637 (bottom), D16682 - 0310 (top)

Figure 57. Post-incident view of splatter and burned material on a mezzanine frame (top) and between the North and South Bran Polishers (bottom) from separated ducts.

Ejected product that was not ignited can be observed in the drone footage. Figure 58 shows ejected product from a roller mill on the 2nd floor on the B-Mill.



06.19.17 Drone Footage at 3:21 (DJI_0003).

Figure 58. Post-incident aerial view from drone footage (cropped) showing ejected product on and near a roller mill in the southern portion of the 2nd floor of B-Mill.

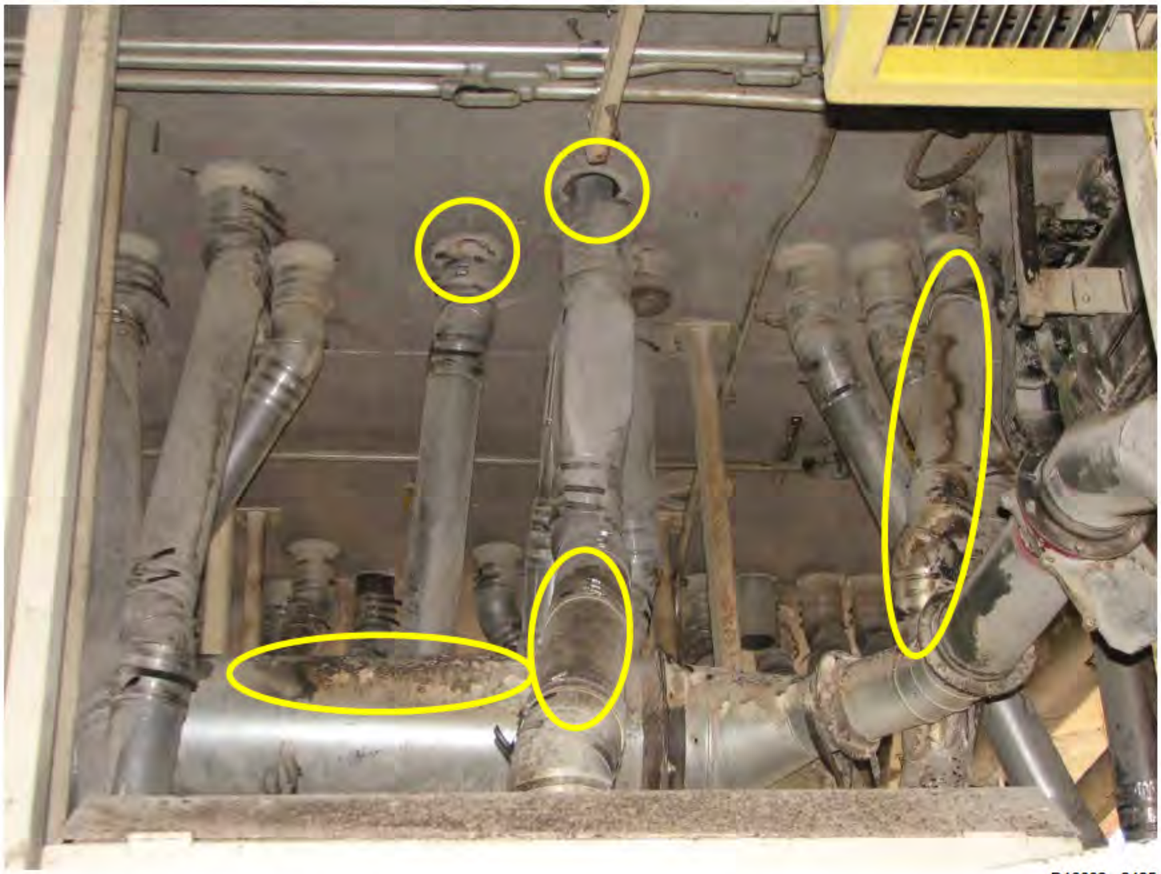
Shown below in Figure 59, additional ejected product that was not ignited can be observed from separated ducts on the 2nd and 3rd floor of the B-Mill.

06.14.17 Drone Footage at 3:23 (DJI_0003)

Figure 59. Drone footage (cropped) showing grain accumulation from severed ducts on 3rd floor of B-Mill and on 2nd floor of B-Mill near roller mill near D-Mill (left). Zoomed in drone footage of grain accumulation from severed ducts on 3rd floor of B-Mill (right).

3.3.1.3 3rd floor of B-Mill (B3)

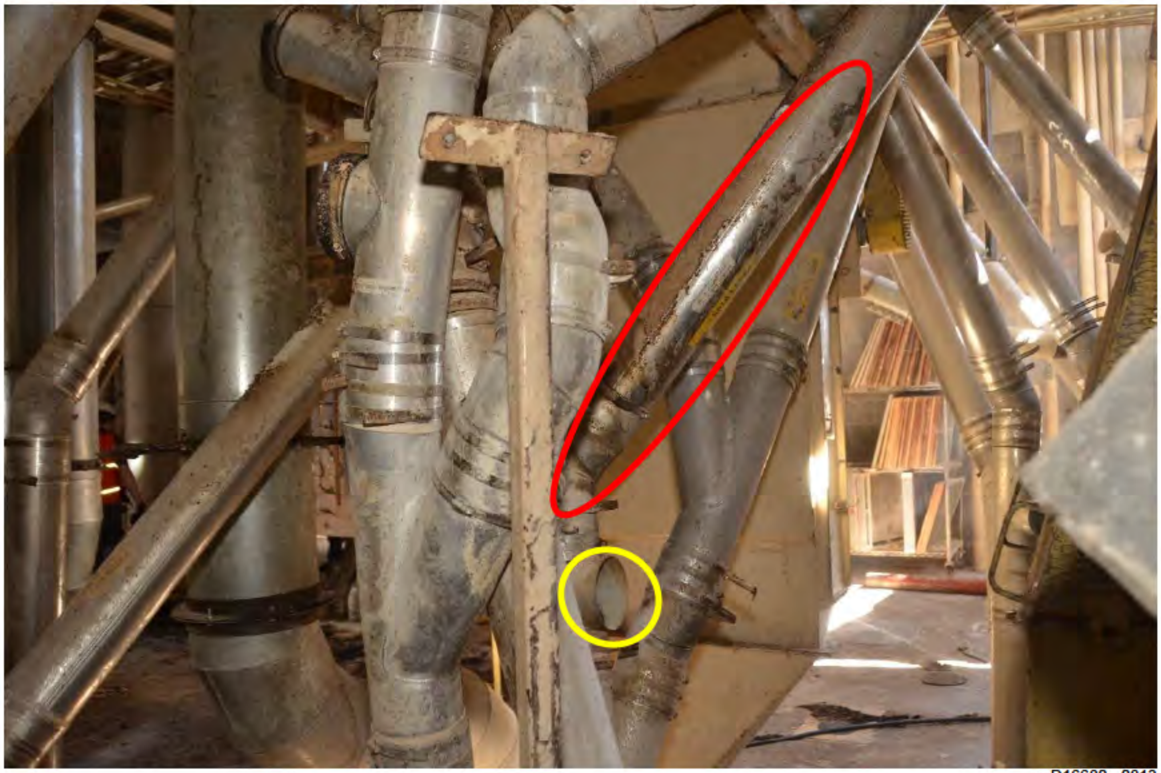
Ejected product is also observed on the 3rd floor of the B-Mill. Multiple separated ducts are observed on B3 as a result of the internal overpressure with ignition of material in various locations as shown below.



D16682 - 0405

Figure 60. Post-incident view of ducting from the 6-section Bran Sifter in the ceiling of B3 that feeds into the North Bran Aspirator. The separated ducts and burn patterns of ejected product are clear evidence of internal overpressure.

As shown in Figure 60, the ducts connecting the North Bran Aspirator on B3 to the 6-section Bran Sifter on B4 are disconnected. There are clear splatter patterns indicative of a deflagration that point toward the duct separations as the source of fuel. Note minimal, if any, fire damage is observed on the ceiling of B3. Additional separated ducting with splatter from burned, projected product is also shown in Figure 61.



D16680 - 0813

Figure 61. Post-incident view of additional ducting on the 3rd floor of the B-Mill exhibiting burn patterns from ejected product splatter.

D16677 - 0848 (cropped – left), D16677 - 0854 (right)

Figure 62. Post-incident view of the 4-Section Sifter on the 3rd floor of B-Mill showing detached caps that were. Burn patterns can be seen on the floor surrounding the ducts. Together these patterns are strongly indicative of internal overpressure displacing these caps and ejecting fuel.

Also on the 3rd floor of the B-Mill is a 4-Section Sifter. As observed on many of the other sifters, the caps were found missing on the bottom ducts, suggesting that they were blown off due to internal overpressure. Figure 62 shows obvious burn patterns on the floor below the 4-Section Sifter. The proximity of black soot to the ducts with detached caps provides evidence that overpressure blew off the caps, material (fuel) ejected from the ducts, and the ejected fuel encountered an ignition source. The 4-Section Sifter is in the Expander 1 and Expander 5 systems, and feeds the Coarse Grinder located in B1, among other locations.[197]

Shown in Figure 63 is the 36" Torit Filter Header in the center of the 3rd floor of B-Mill that contains 2 blinds: a 12" line and 20" line.

[197] REF-MILL-ENG 6601-01.

D16686 - 00959 (left), D16686 - 00961 (right)

Figure 63. Post-incident view of 12" and 20" blinded lines that were connected to the 36" Torit Filter Header in B3 (left) and zoomed-in end of 20" line (right).

Burned residue of expelled product from the end of the 20" line is observed on surrounding walls and ceiling (Figure 63, left). The 20" blind itself is observed to be deformed from the overpressure that developed in the 36" Torit Filter Header in B3 (Figure 63, right).

Additional soot deposition from burned product projected from an open duct on the 3rd floor of the B-Mill can be observed in Figure 64.

D16686 - 00972

Figure 64. Post-incident view of soot deposition from burned product projected from an opened duct on the 3rd floor of B-Mill.

3.3.1.4 4th floor of B-Mill (B4)

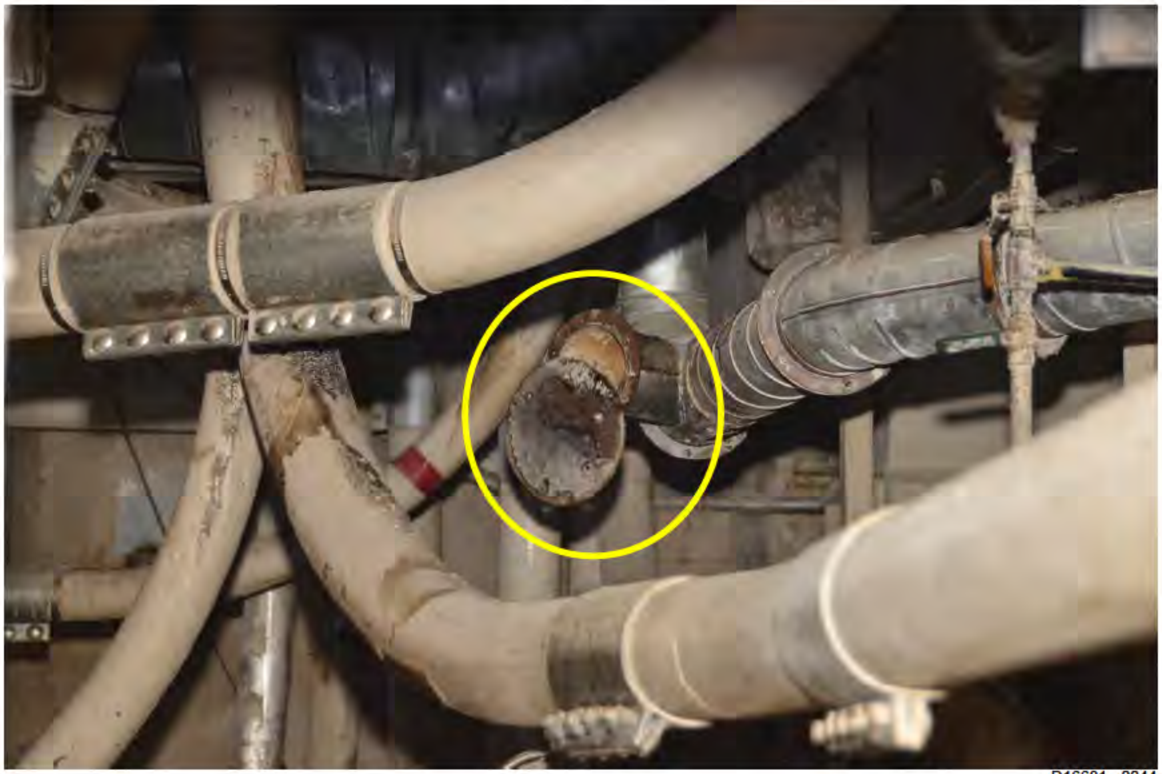
The 6-Section Bran Sifter on the 4th floor of the B-Mill was also found without caps on its ducts, consistent with the hypothesis that internal overpressure blew the caps off (Figure 65).

D16682 - 0478

Figure 65. Post-incident view of the 6-Section Bran Sifter on the 4th floor of B-Mill with detached caps as a result of internal overpressure.

3.3.2 Material Ejected in A-Mill

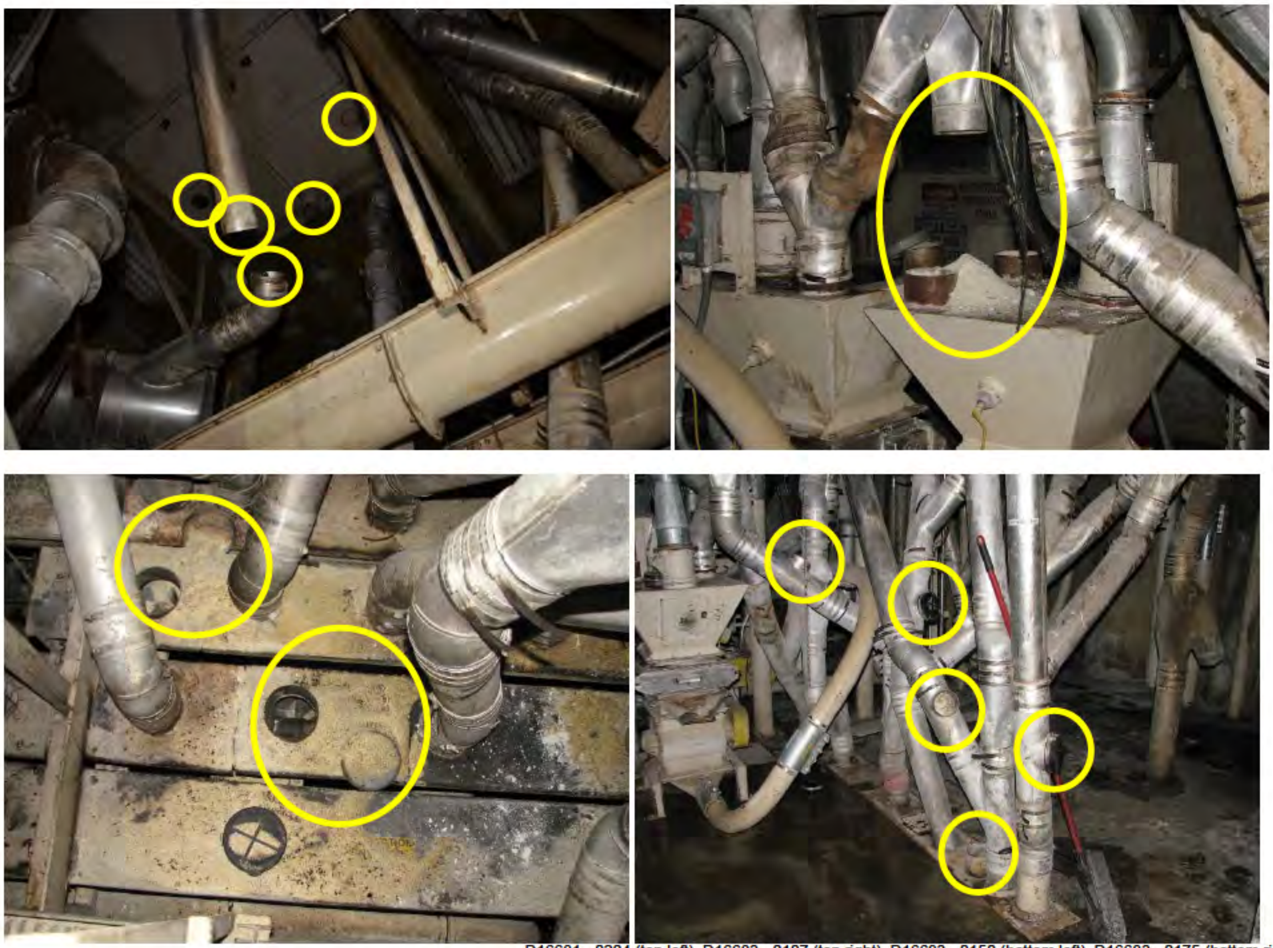
The A-Mill also shows evidence of blind ducts that experienced an internal overpressure event and of soot deposition from burned, ejected material, as shown in Figure 66.



D16681 - 0044

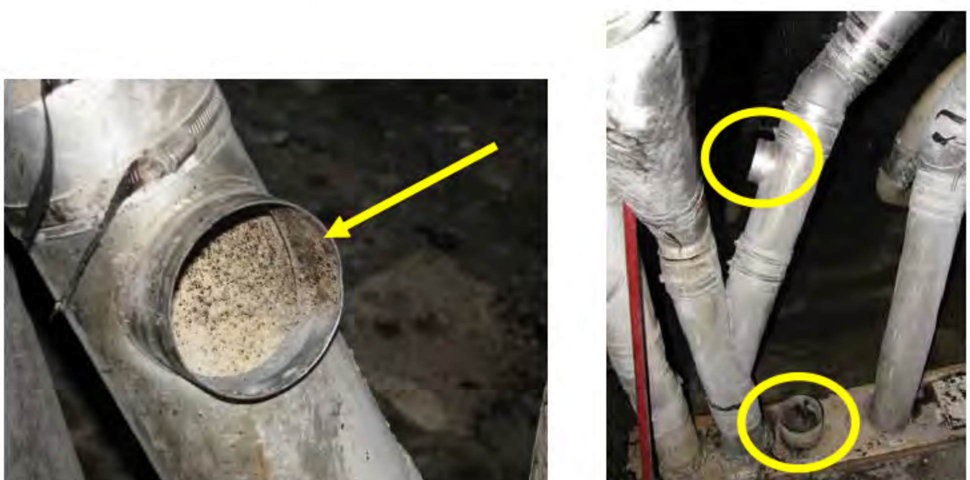
Figure 66. Post-incident view of a separated flange in A1.

In addition to the ducts that separated due to the internal overpressure experienced in the A-Mill, multiple locations show burned grain deposited on the inside of the ducts, as shown in Figure 67 and Figure 68. Photographic evidence of detached caps and ejected product are indicative of internal overpressure propagating inside equipment and through ducting. While explosions may have occurred outside of equipment, the evidence overwhelmingly demonstrates that the pathway for propagation was interior to equipment, and the propagation from one mill to the next occurred through internal ducting. This mechanism is supported through numerous instances of photographic evidence of burn patterns inside the ducts and of detached caps, consistent with internal overpressure. An external overpressure event would not have caused the same overpressure or burn patterns observed in this section.



D16681 - 0204 (top left), D16683 - 0107 (top right), D16683 - 0150 (bottom left), D16683 - 0175 (bottom right)

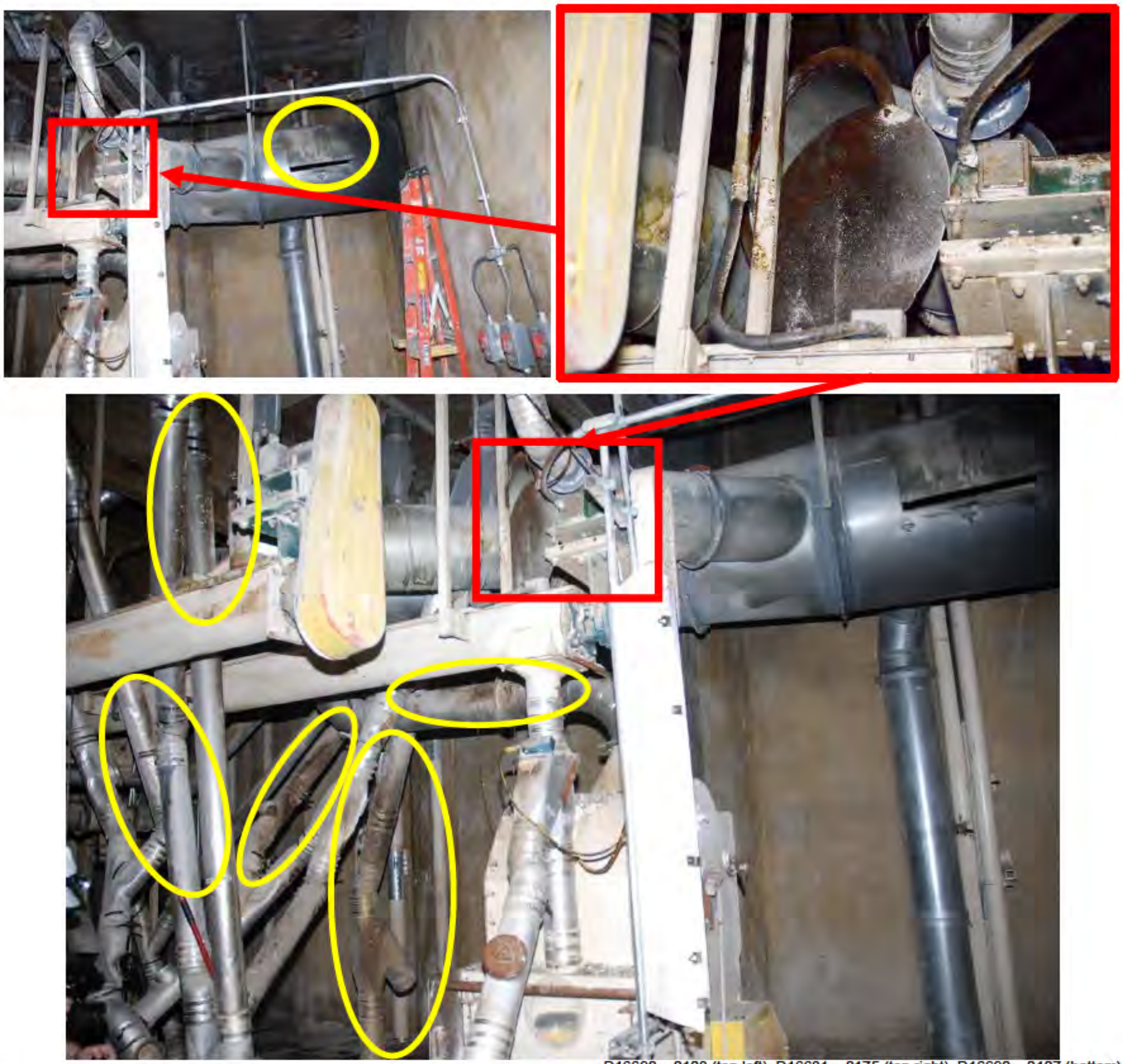
Figure 67. Post-incident view of separated ducts and detached caps in A2 as a result of internal overpressure. Material was apparently ejected from these openings as a result.



D16683 - 0177 (left), D16683 - 0181 (right)

Figure 68. Post-incident view of burned grain inside ducting in the A-Mill (2nd floor).

As discussed in Section 3.2.2, the Torit Filter header extended from the 36" Torit Filter Header which spanned across the F-Mill, B-Mill, and A-Mill. This header had blinds installed as shown in Figure 69.



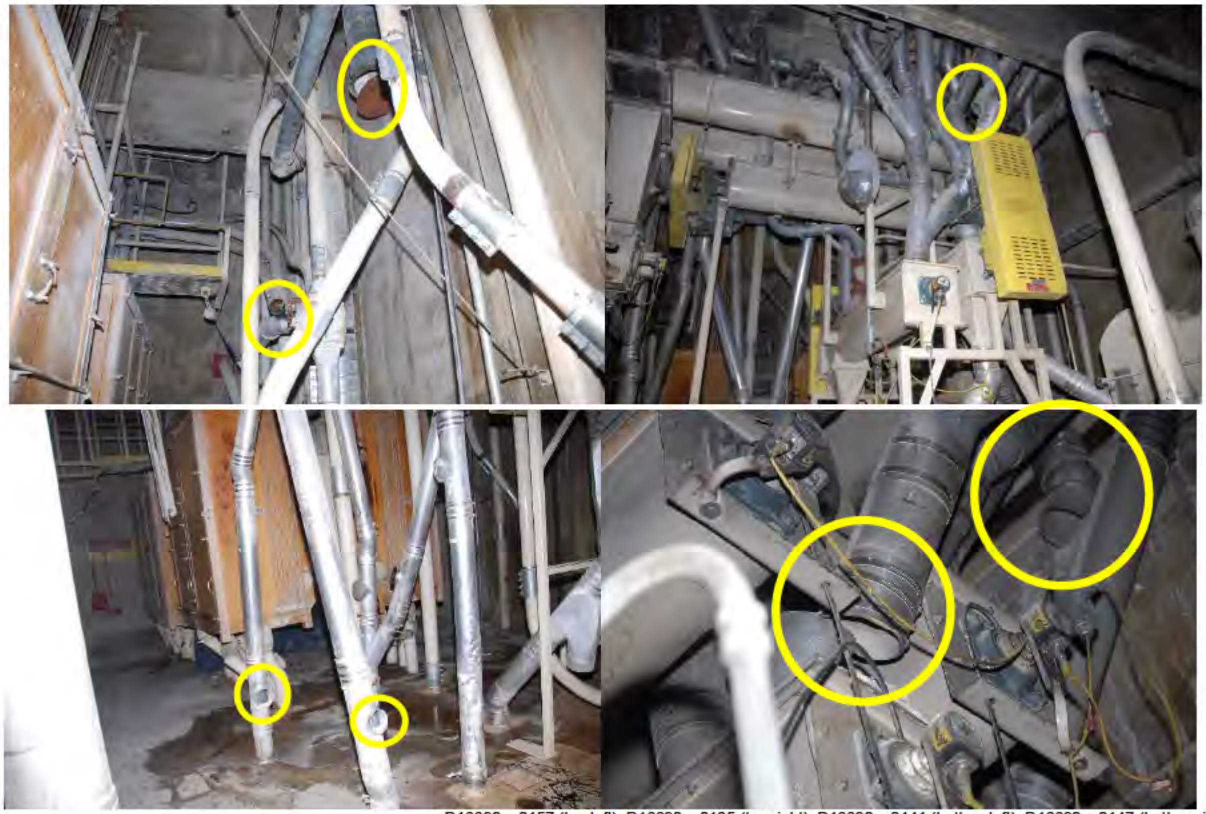
D16690 – 0108 (top left), D16681 – 0175 (top right), D16690 – 0107 (bottom)

Figure 69. Post-incident view of Torit Filter Header entering the 2nd floor of the A-Mill (top left) with the access door and blind blown off due to internal overpressure in Torit Filter Header (top right) resulting in burn splatter on surrounding piping in A-Mill (bottom).

As observed in Figure 69, a clear overpressure occurred on the 2nd floor of the A-Mill where the Torit Filter Header entered the building. In the top left photo, the access door on the 36" Torit Filter Header is shown to have popped open due to internal overpressure. As seen in the top

right image, the blind is observed to be blown off with soot deposition along the blind and flange. In the bottom image, the splatter of burned fuel (mill product) on surrounding ducts can be observed from the opened blind.

As described later in Section 3.4.2.3, the internal overpressure spread throughout the A-Mill through the equipment and ducting. Additional photos showing the overpressure experienced in ducts on the 3rd floor of the A-Mill are shown below in Figure 70.



D16690 – 0157 (top left), D16690 – 0135 (top right), D16690 – 0141 (bottom left), D16690 – 0147 (bottom right)

Figure 70. Post-incident view of process lines that have been separated or had their flanges or caps blown off by the event in the A-Mill (3rd floor).

In addition to the clear, internal overpressure event(s) observed throughout the Mills, the material ejected from the 6-Sifter on the 3rd floor of A-Mill ignited, as shown in Figure 71. This conclusion is supported by the clear burn patterns on the ground of A3 and by the open ducts beneath the sifter leading to A2 with detached caps that were blown off by the ejection of material.

Figure 71. Post-incident view of 6-Section Sifter on 3rd floor of A-Mill with clear burn patterns on the ground and caps blown off ducts below the sifter going into the 2nd floor of the A-Mill.

Additional evidence of internal overpressure is shown on the 5th floor of the A-Mill through the Grit/Flour Sifter (M-11021; Figure 72) and process lines on the 5th floor of the A-Mill (Figure 73).

Figure 72. Post-incident view of the Grit/Flour Sifter (M-11021) on the 5th floor of the A-Mill. Yellow circles indicate detached ducts and caps as a result of internal overpressure.

D16681 - 0425 (top left), D16681 - 0452 (top right), D16681 - 0458 (bottom left), D16681 - 0460 (bottom right)

Figure 73. Post-incident view of process lines that have been separated or had their flanges or caps blown off by the event in the A-Mill (5th floor).

3.3.3 Material Ejected in D-Mill

Although the D-Mill was unsafe to access directly during Exponent's scene inspection, drone footage shows extensive ejection of product due to internal overpressure in ducts releasing material into the mill. Conversely, drone footage demonstrated very little (if any) evidence of external explosion propagation within the D-Mill.

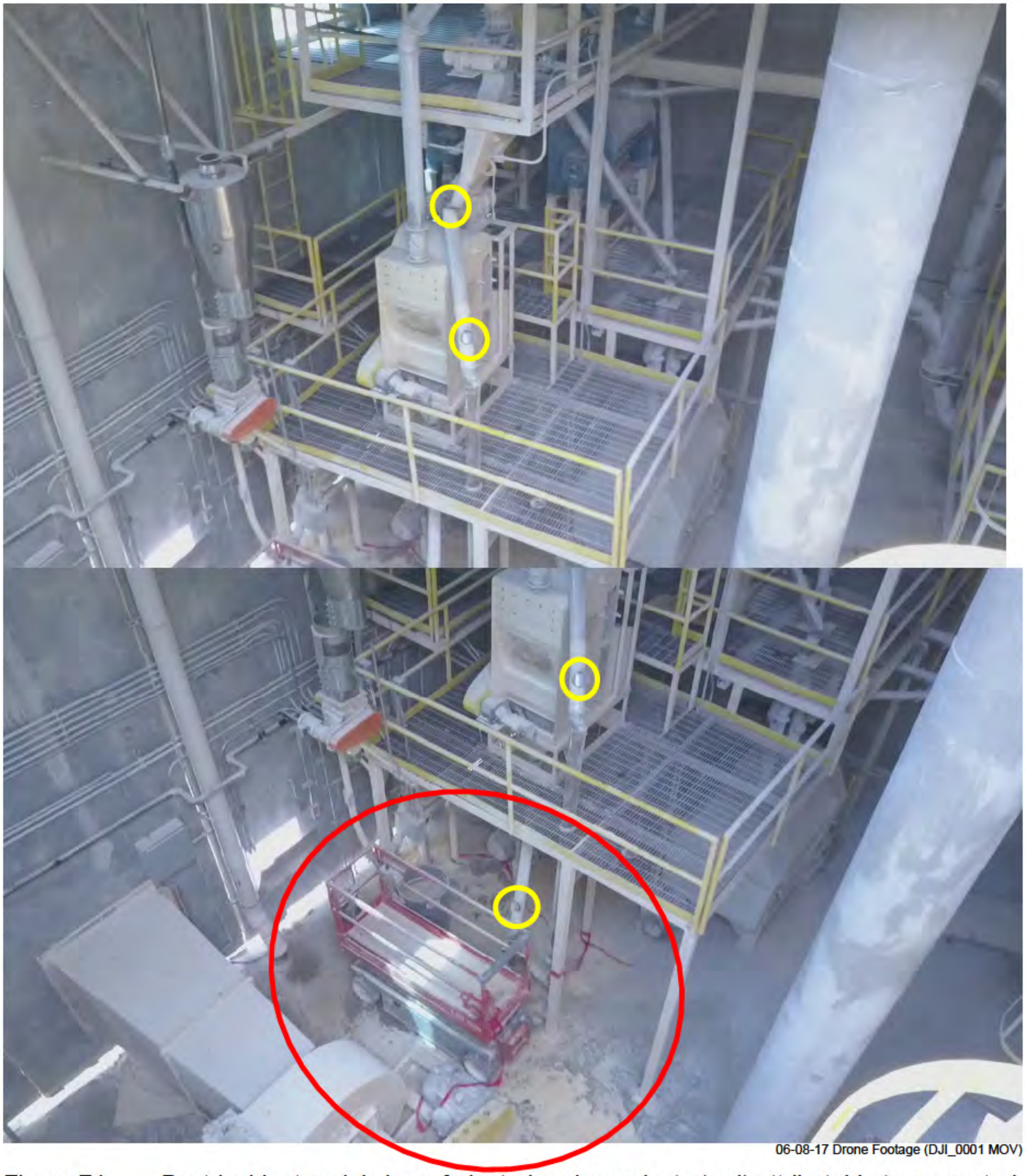


Figure 74. Post-incident aerial view of ejected grain products (red) attributable to separated ducts (yellow), both of which are indicative of internal overpressure in the D-Mill.

3.4 Opinion 4: Explosion in Dry Grit Filter and other areas

Opinion 4: *The explosion in B1 was shortly followed by an explosion in the Dry Grit Filter. The explosion occurred due to internal propagation through process and dust collection equipment, and the most direct propagation pathway was through the Government Line lift gate located underneath the damaged fan downstream of the SBM. The propagation of the explosion through the Dry Grit Filter header provided pathways to equipment in both the Pack area and the Product Protection System (PPS) area. Propagation of the explosion into the Pack and PPS areas via this header may have contributed to the damage in these areas.*

As described in the following subsections, an explosion propagated internally through the dust collection system serving the Dry Grit Filter. There were two opportunities within B1 for flame to be ingested into a product lift line serving the Government Line—an air intake filter that clearly ingested flames (shown in Figure 77), and a lift gate that was typically open during operation (shown in Figure 76). The lift gate was after the point of product addition, directly downstream of the Government Heat Treat located on the 2nd floor of the B-Mill and the air intake filter located on the 1st floor of the B-Mill.

3.4.1 B1 to Dry Grit Filter (through Government System)

The explosion that occurred in B1 was able to enter the Government System through the Government Line lift gate located on B1, under the mezzanine that held the SBM and NBM Fans discussed in Section 3.2.1. Figure 75 shows the top of the Government Line lift gate, just below the SBM and NBM fans and the air intake filter to the right of the SBM fan.

Figure 75. Post-incident view of the Government lift gate shown below the NBM and SBM Fans in B1. The air intake can be seen on the right, behind the SBM Fan.

A more comprehensive view of the Government Line lift gate in B1 is shown below in Figure 76.

D16686 - 00352 (top), D16686 - 00356 (bottom)

Figure 76. Post-incident view of Government Line lift gate (top) with zoomed in photo of the lift gate slightly open (bottom) on B1.

The Government Line lift gate is a part of the Government System. The open portion shown in the bottom of Figure 76 is used to readily open or shut based on the system's needs. As described by the manufacturer:[198]

> *Kice SGH Streamguard Blender Fittings serve as an acceleration zone for pneumatically conveyed stocks and also as an automatic release for overload quantity. When suction requirements for conveying exceed vacuum being developed by fan, the counter-weighted gate will fall away and permit excess stock to drop out of the system. When overload condition is corrected, air speed naturally increases and pulls gate back into place. Standard with adjustable makeup air inlet.*

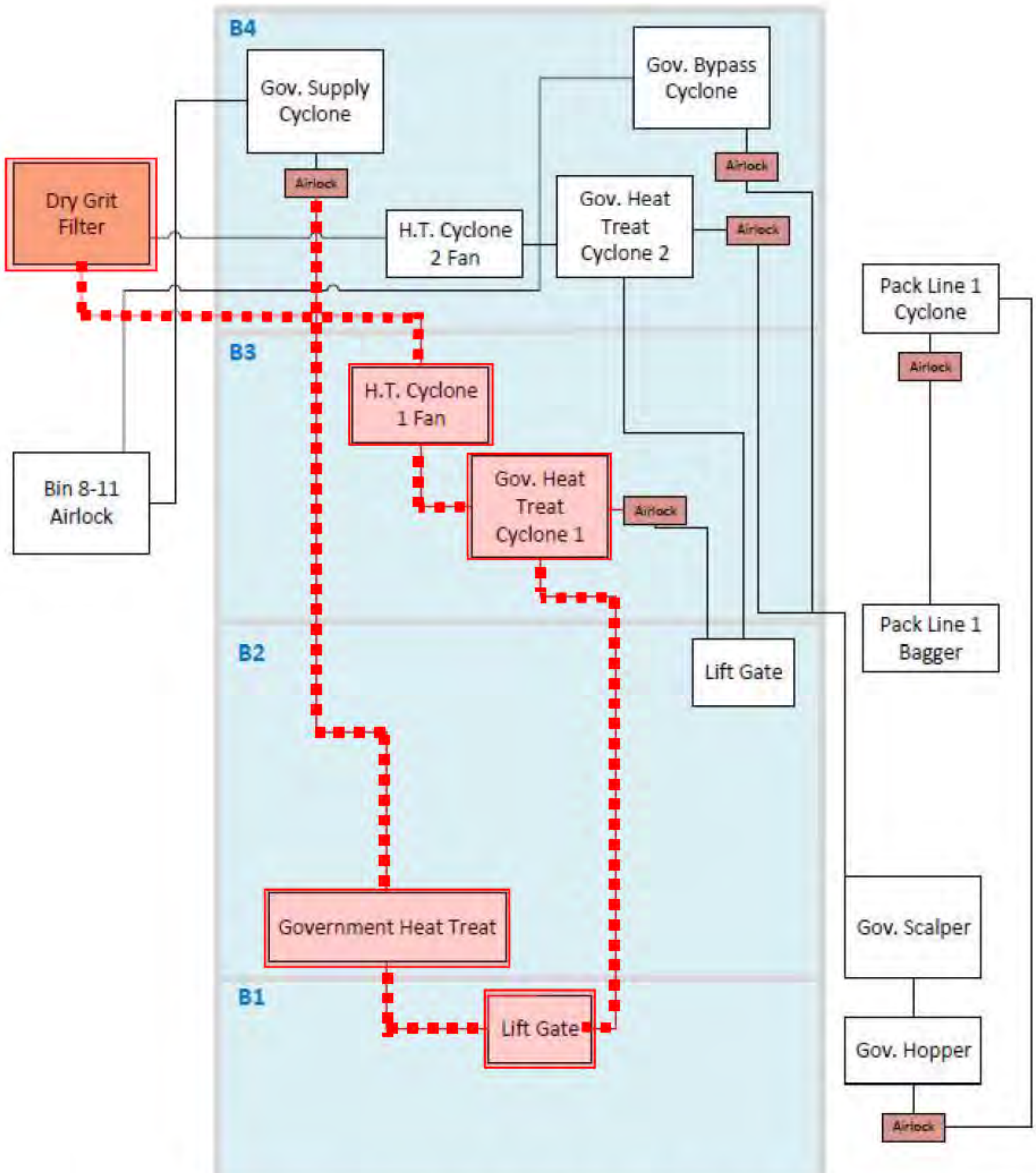
Discussions with Didion employees during the scene inspection indicated that this air inlet was typically in the open condition. In addition to the Government Line lift gate, there was an air intake with filter location shown in Figure 77.

D16686 - 00386

Figure 77. Post-incident view of air intake line on Government Line in B1.

Thermal damage to the filter at the inlet to the Government Line can be observed from Figure 77. The damage indicates that the line was under suction at the time of the explosion in B1, providing multiple opportunities for flame to be ingested into the process line, at the filter and the lift gate. While no combustible dust would be expected just inside the filter, a mixture of material (fuel) and air would be expected just inside the lift gate, providing a pathway for flame to enter the government system. Once in the Government System, the flame propagated to other pieces of equipment shown in Figure 78.

[198] Kice Streamguard Blender Fitting | Kice Industries, Inc; Speed_Spout_Manual.pdf (kice.com)



Adapted from Highlighted PFDs – Government Heat Treat and LO pdf and REF-MILL-ENG-8601-01 Gov Packaging System Process Flow S#01 pdf

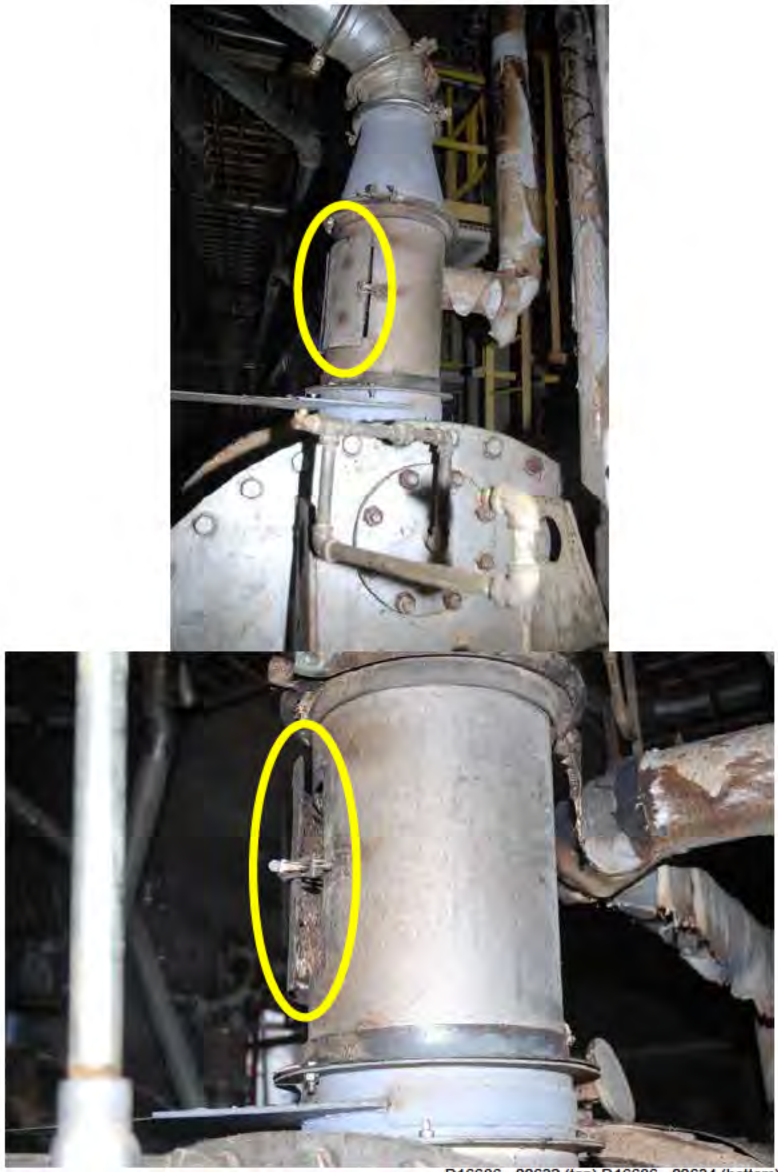
Figure 78. PFD of the Government System in the B-Mill with propagation pathway shown in red.

After entering the Government Line lift gate in B1, the flame/explosion was able to propagate back into the Government Heat Treat located on B2 and in Figure 79. While much of the

Government System is enclosed, there is a door on the top of the Heat Treat Eclipse. Close-up photographs of this access door are shown below in Figure 80. From these photographs, the access door on the Government Heat Treat Eclipse is shown to have opened during the incident, and charred fuel is seen on the inside of the door from the flame/explosion propagation, consistent with a propagation event initiating at the Government Line lift gate in B1.

D16686 - 00595

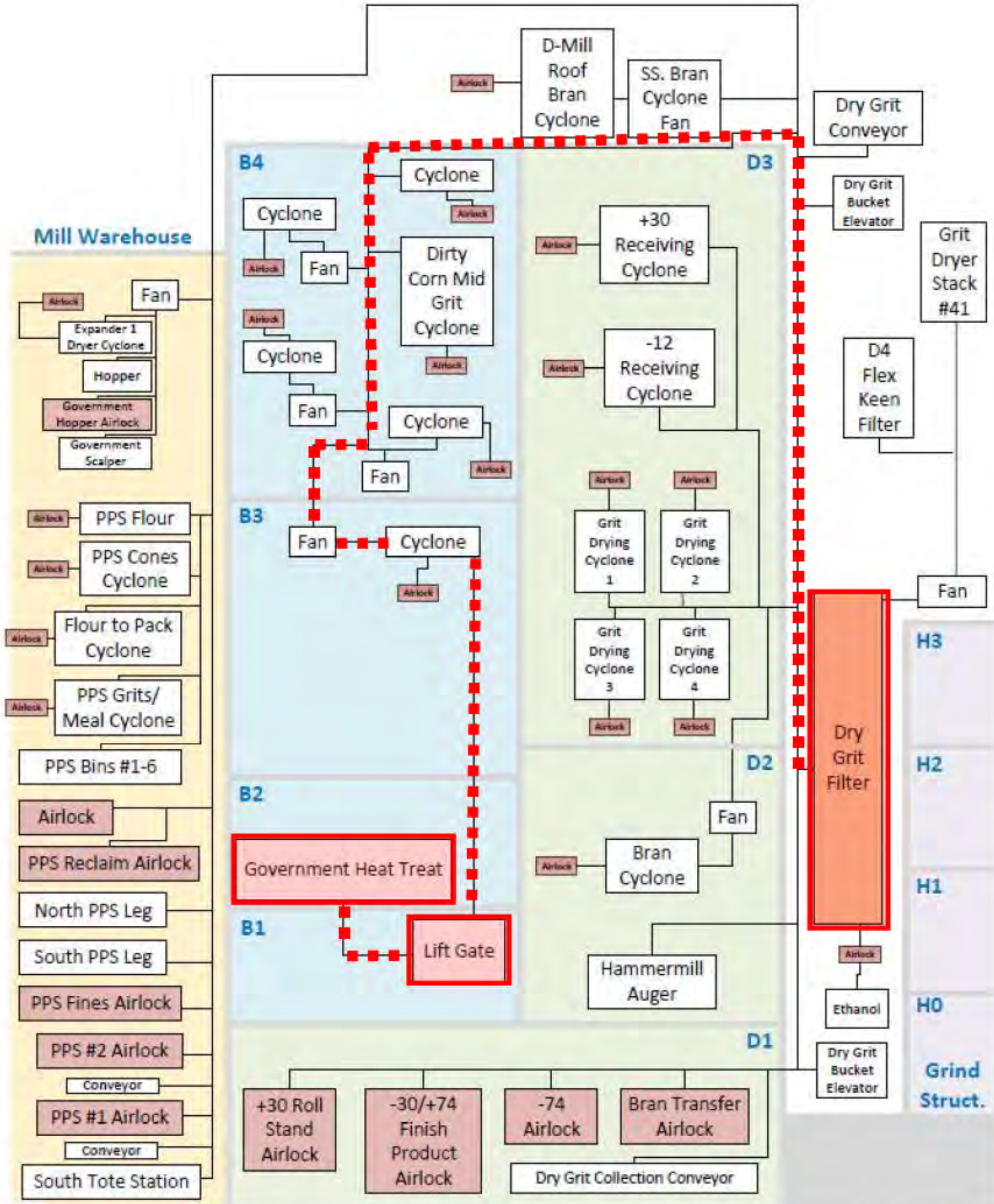
Figure 79. Post-incident view of Government Heat Treat Eclipse on 2nd floor of B-Mill.



D16686 - 00632 (top) D16686 - 00634 (bottom)

Figure 80. Post-incident view of Government Heat Treat Eclipse on 2nd floor of B-Mill (zoomed in).

As seen in Figure 78, this flame entered through the Government Line lift gate in B1 and spread through other equipment eventually reaching the Dry Grit Filter. Other equipment between the Government Line lift gate in B1 and the Dry Grit Filter include the Government Heat Treat Cyclone 1 located on the 3rd floor of the B-Mill. The flame/explosion that occurred in the 1st floor of the B-Mill was able to spread through the Government System and into the Dry Grit Filter, which was connected to the other areas of the Mill as shown in Figure 81.

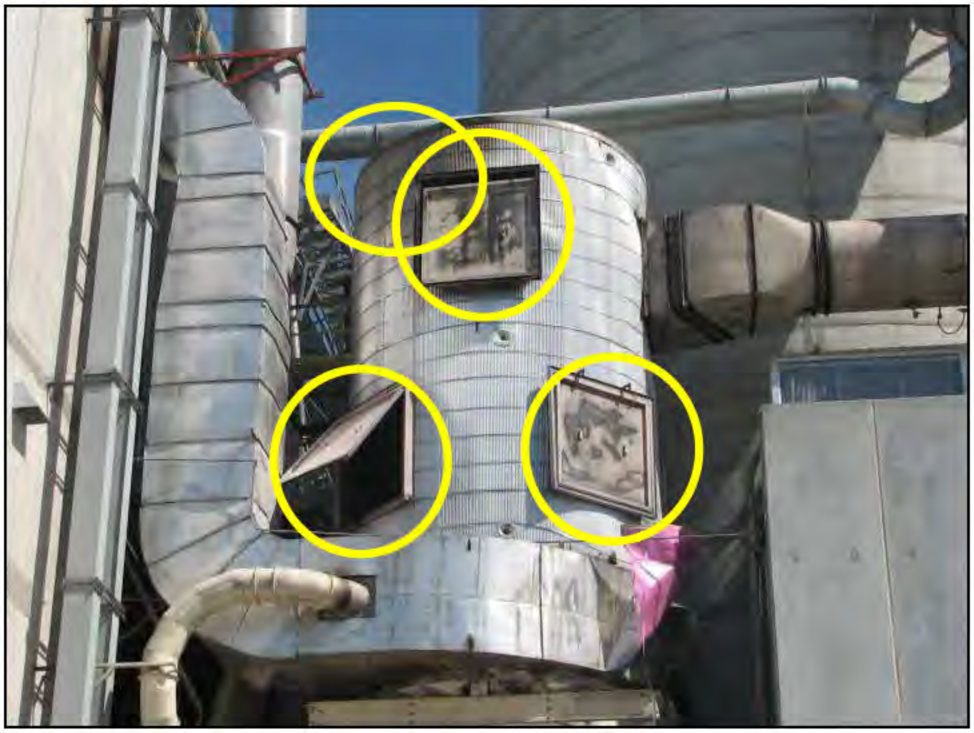


Adapted from REF-MILL-ENG-7803-01 F6 Dry Grit Filter S#3.pdf and Highlighted PFDs - Government Heat Treat and LO.pdf

Figure 81. Flame Propagation from B1 to the Dry Grit Filter, which is connected to rest of Mill (Warehouse, B-Mill, D-Mill, and Grind Structure). The propagation pathway from the government system to the dry grit filter is shown in red.

3.4.2 Dry Grit Filter to rest of Mill (Warehouse, B-Mill, D-Mill, and Grind Structure)

The Dry Grit Filter was located on the outside of the D-Mill shown below in Figure 82. This piece of equipment was located outside of the mill buildings but connected through multiple ducts to different areas of the mill (Mill Warehouse, B-Mill, D-Mill, and Grind Structure) shown previously in Figure 81. Witnesses observed an explosion venting from the Dry Grit Filter within seconds of the explosion in B1.[199,200] Figure 82 shows the open explosion panels on the Dry Grit Filter, consistent with this observation. The only viable means for propagation of an explosion to the Dry Grit Filter was *internally* through the ducts that feed it.



D16641 – 0084 (cropped)

Figure 82. Post-incident view of Dry Grit filter mounted to side of D-Mill.

3.4.2.1 Dry Grit Filter to D-Mill

The ducting from the Dry Grit Filter going into the top of the D-Mill is connected to additional ducting inside the D-Mill as shown in Figure 83. Four Grit Drying Cyclones that also feed the Dry Grit Filter in the D-Mill are shown below in Figure 84. As observed in the photo, extensive

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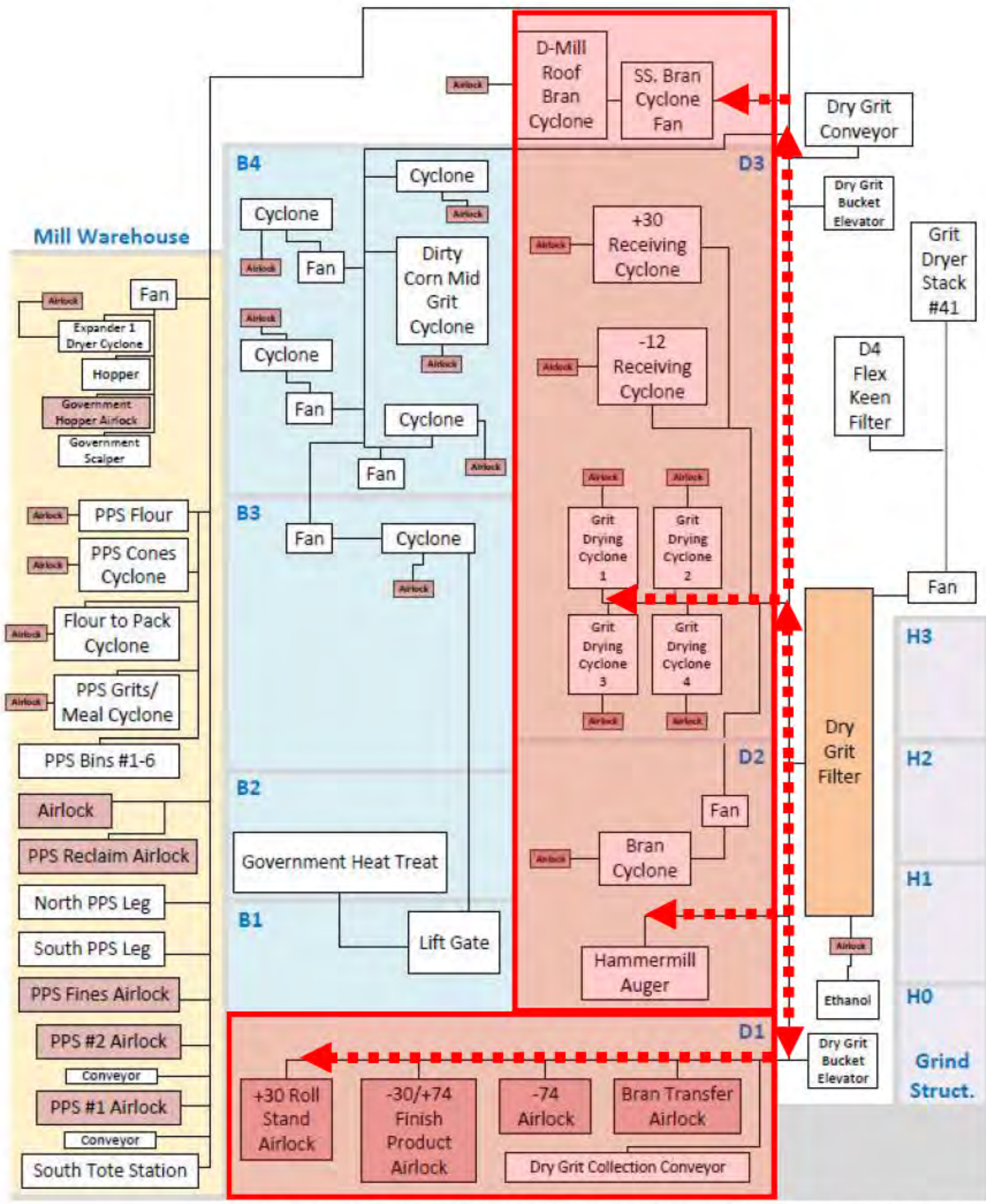
199 Deposition Transcript of [redacted], May 13, 2021. pp. 146-147.

200 U.S. Chemical Safety and Hazard Investigations Board Interview of [redacted]. July 11, 2017. p. 11. GJ_CSB_0005692.

fire damage occurred from the inside the duct between the Dry Grit Filter and the Grit Drying Cyclones in the D-Mill. Additional equipment was affected within the D-Mill but was unable to be photographed extensively due to safety concerns regarding the building's post-explosion integrity. The drone footage captured shows internal overpressure experienced in the D-Mill equipment (from the caps blown off lines and flattened ducts) resulting in extensive ejection of products as shown in Figure 85.

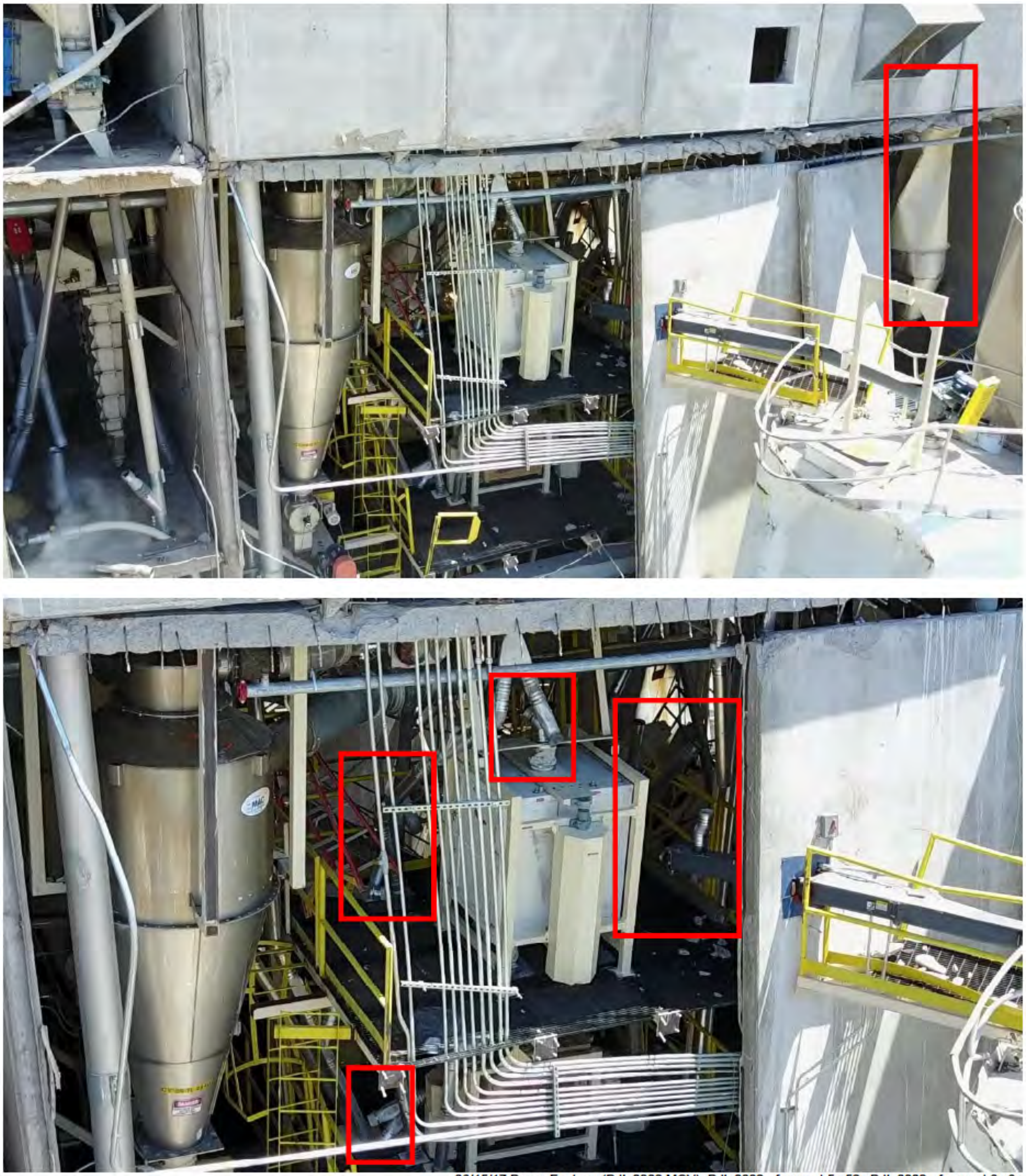


Adapted from REF-MILL-ENG-7803-01 F6 Dry Grit Filter S#3.pdf and Highlighted PFDs - Government Heat Treat and LO.pdf

Figure 83. Dry Grit Filter to D-Mill with propagation shown in red.

Figure 84. Post-incident aerial view of duct connecting the Dry Grit Filter and Grit Drying Cyclones in the D-Mill.

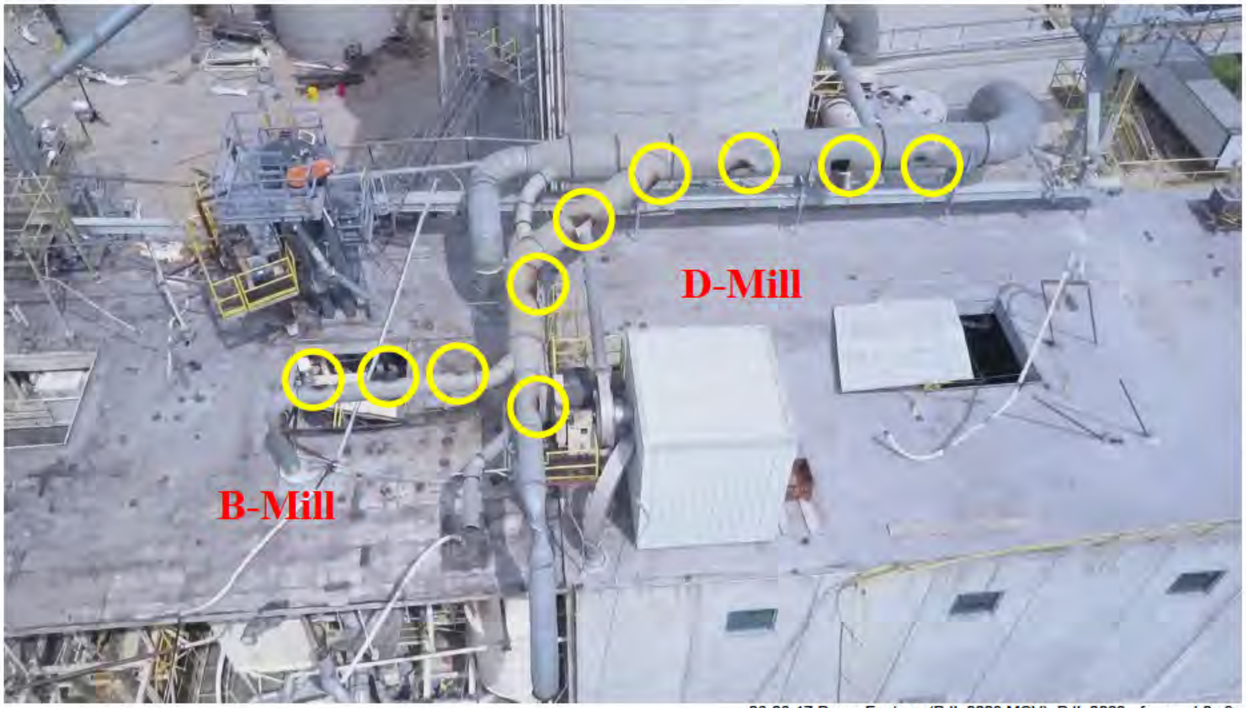
Drone footage from the D-Mill showed separated ducts in Figure 74 (described above in Section 3.3.2 with material ejected into the D-Mill). Additional drone footage from outside of the D-Mill captured other ducting and equipment. From Figure 85, internal overpressure is observed due to caps blown off ducting attached to equipment and collapsed ducting (described in more detail in Section 3.4.2.3.1). The Dry Grit Filter ducts are connected to multiple pieces of equipment in the D-Mill including D1 but no drone footage or photographs inside were captured due to the inaccessibility of location and building stability concerns, respectively.



06/15/17 Drone Footage (DJI_0002 MOV). DJI_0002 - frame at 5m52s DJI_0002 - frame at 6m8s

Figure 85. Post-incident aerial view of D1 equipment showing internal overpressure.

From Figure 85, multiple disconnected ducts are observed. In the top screenshot from drone footage, a collapsed duct can be seen, which is a phenomenon associated with the vacuum pressure that follows an internal deflagration.[201] In addition to the equipment throughout the D-Mill, ducting from the Dry Grit Filter to the other areas of the mill can be observed on top of the D-Mill connected to the D-Mill Bran Cyclone and fan in Figure 86.



06-08-17 Drone Footage (DJI_0003.MOV). DJI_0003 - frame at 0m9s

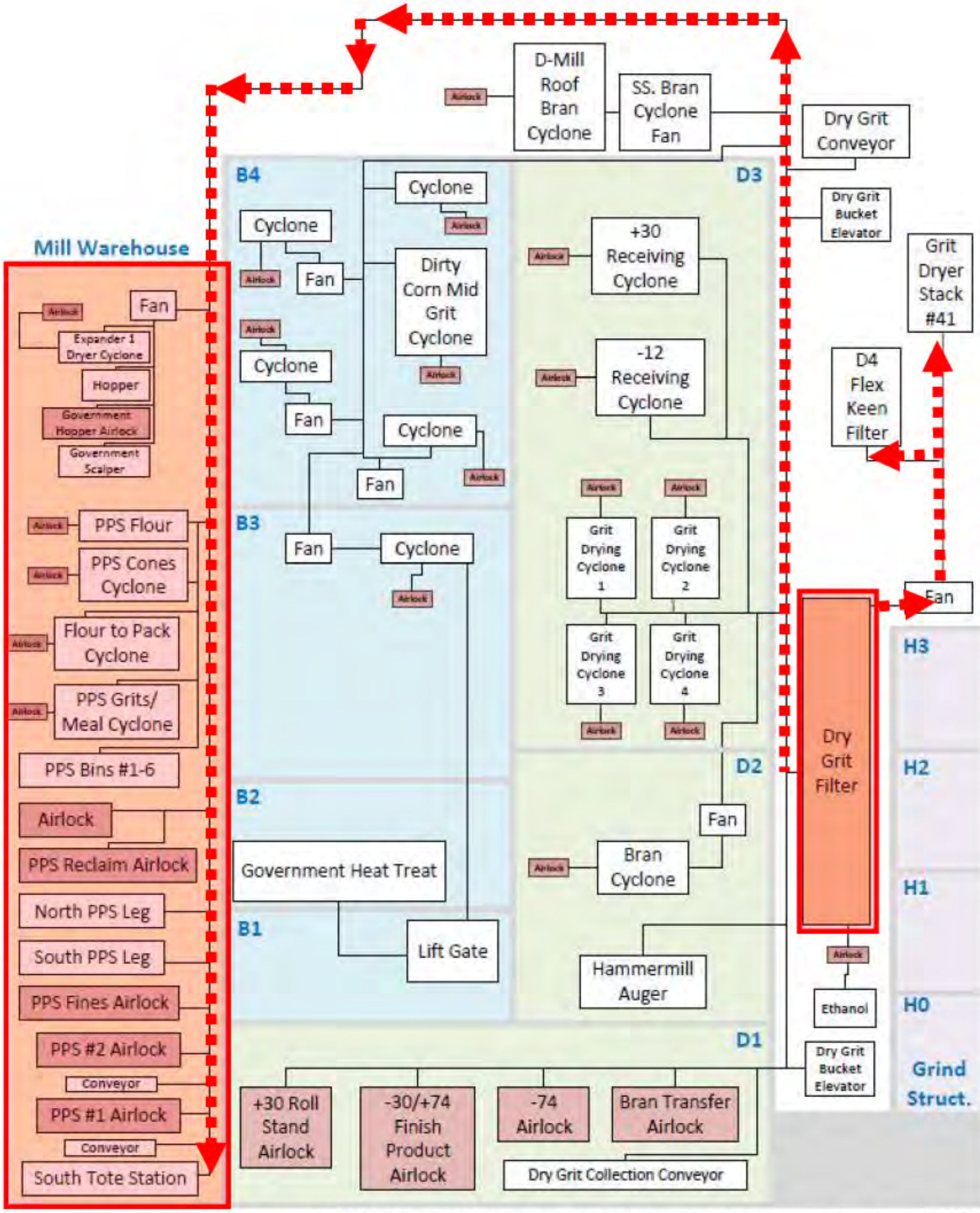
Figure 86. Post-incident aerial view of ducting connecting the B- and D-Mill to the Dry Grit Filter.

From Figure 86, the branched connections from the Dry Grit Filter header to the individual pieces of equipment showed extensive soot from the inside of the ducting escaping at the connections. Multiple access points were also blown off due to internal overpressure event(s).

3.4.2.2 Dry Grit Filter to Warehouse

As shown by the ducting in Figure 86 going to the B-Mill and the PFD in Figure 87 going to the warehouse, the Dry Grit Filter spanned multiple areas of the Mill.

[201] Cox B., Hietala D., Ogle R. (2021). Dust explosions and collapsed ductwork. J. Loss. Prev. Process Ind. 69, 104350.



Adapted from REF-MILL-ENG-7803-01 F6 Dry Grit Filter S#3.pdf and Highlighted PFDs - Government Heat Treat and LO.pdf

Figure 87. Dry Grit Filter to rest of Mill (Warehouse, B-Mill, D-Mill, and Grind Structure) with propagation shown in red.

As shown in the F6 Dry Grit Filter PFD,[202] the Dry Grit Filter spanned the D-Mill, B-Mill, and Warehouse in addition to the roof of the Grind Structure (also referred to as "Hammermill"). In the warehouse, the Dry Grit Filter was connected to multiple pieces of equipment in both the Pack area and the Product Protection System (PPS) area. While the warehouse was inaccessible after the incident, the PFDs show that this system was interconnected across multiple other areas of the mill through the Dry Grit Filter header. Due to the extent of damage and collapse in these areas, the extent of internal propagation into the Pack and PPS areas could not been determined, but it is likely that some amount of propagation occurred given the extensive evidence of propagation elsewhere in the Dry Grit Filter header.

3.4.2.3 Dry Grit Filter to A-Mill

The Dry Grit Filter was shown in the PFDs associated with the A-Mill flow to be connected to the Dry Grit Transfer Conveyor on the 6th floor of the A-Mill.[203] The Dry Grit Transfer Conveyor directly fed the Grit Sifter Conveyors that directly connected to the Grit/Flour Sifter (M-11021) on the 5th floor of the A-Mill (shown in Figure 88) and the Spreader Feed Conveyor that directly connected to the A-Mill Sizing 6-Section Sifter (M-11014) on the 4th floor of the A-Mill (shown in Figure 89). The two sifters shown below fed multiple other pieces of equipment downstream in the A-Mill.[204,205]

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[202] REF-MILL-ENG-7803-01 F6 Dry Grit Filter S#3.pdf

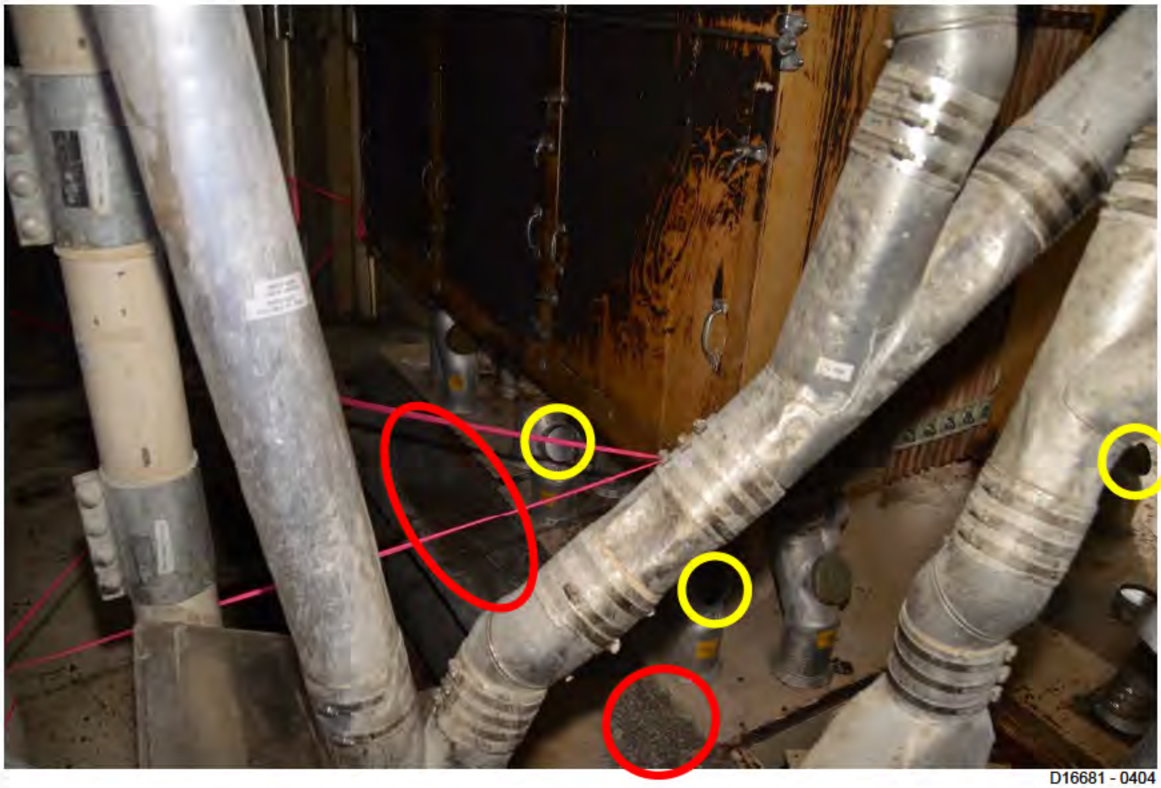
[203] REF-MILL-ENG-5001-01 A-Mill Flow S#1.pdf

[204] REF-MILL-ENG-5001-01 A-Mill Flow S#1.pdf

[205] REF-MILL-ENG-5002-01 A-Mill Flow S#2.pdf

D16090 - 0281

Figure 88. Post-incident view of Grit/Flour Sifter (M-11021) on the 5th floor of the A-Mill.



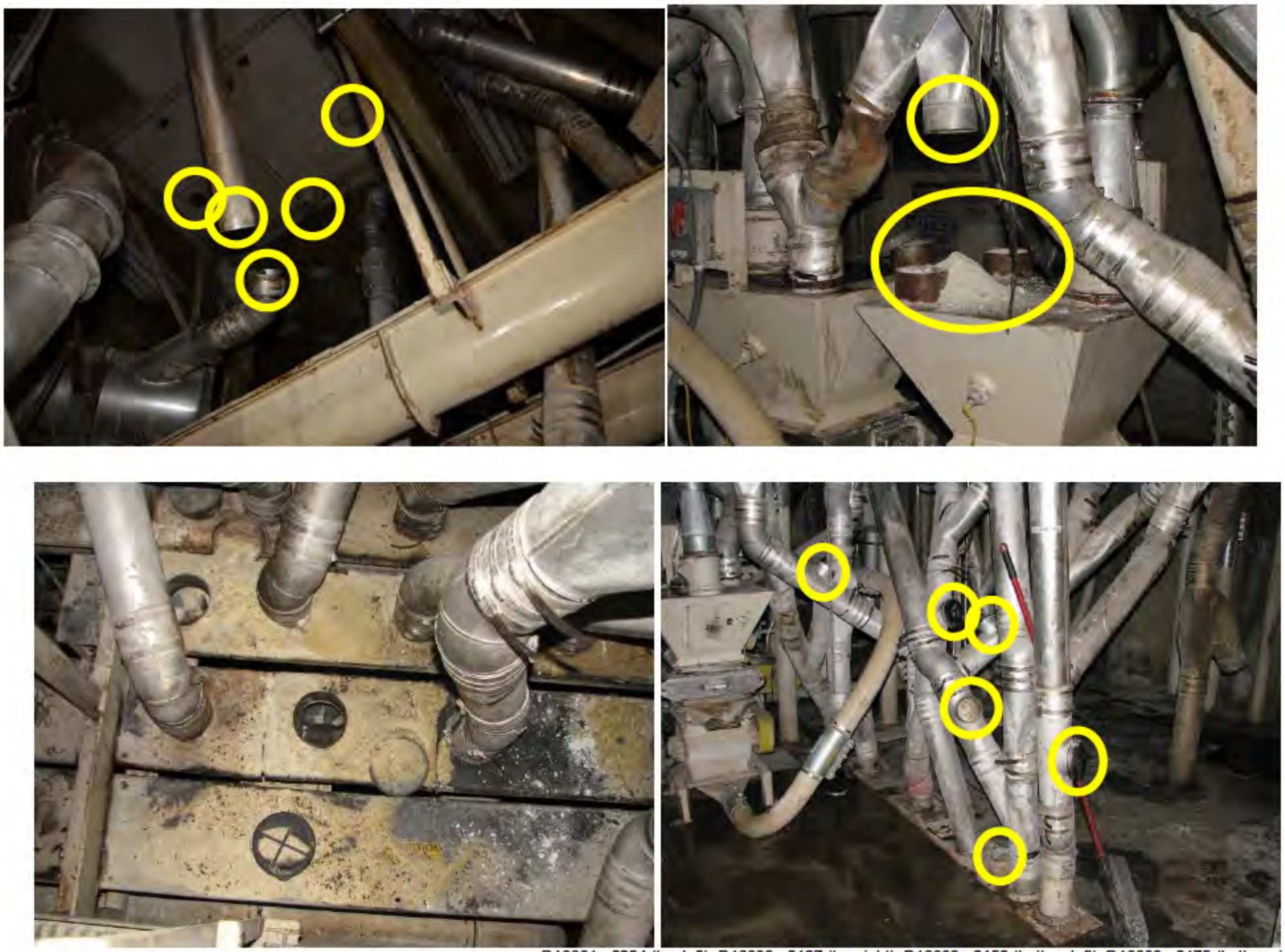
D16681 - 0404

Figure 89. Post-incident view of A-Mill Sizing 6-section sifter (M-11014) on the 4th floor of the A-Mill with caps blown off due to internal pressure (yellow) and burns on the floor from ignited ejected product (red).

Both of the sifters connected to the Dry Grit Filter in the A-Mill showed internal overpressure, observed from the caps blown off the bottom ducts from these pieces of equipment. These sifters fed into Reduction Roll Stands on A1, which fed the Sizing Flour 6-Section Sifter on the 3rd floor of the A-Mill, shown in Figure 90.

Figure 90. Post-incident view of Sizing Flour 6-Section Sifter on the 3rd floor of the A-Mill with caps blown off due to internal pressure (yellow) and burns on the floor from ignited ejected product (red).

As observed in Figure 90, the outlet ducts from the bottom of the 6-section sifter also experienced overpressure, which resulted in the caps being blown off. There are also burns on the floor of this sifter from ejected material ignited, discussed previously in Section 3.3. This sifter fed multiple pieces of equipment downstream on the 2nd floor of the A-Mill shown below in Figure 91.



D16681 - 0204 (top left), D16683 - 0107 (top right), D16683 - 0150 (bottom left), D16683 - 0175 (bottom right)

Figure 91. Post-incident view of A-Mill observations of separated ducts or caps blown off due to internal overpressure (2nd floor).

In addition to the separated ducts from the internal overpressure experienced in the A-Mill, multiple locations showed burned grain deposited on the inside of the ducts, as can be seen in Figure 91. This is indicative of an internal overpressure inside the equipment propagating through the ducting as compared to an external overpressure event associated with fugitive dust within the building compartment.

D16683 - 0177 (left), D16683 - 0181 (right)

Figure 92. Post-incident view of burned grain inside ducting in the A-Mill (2nd floor).

3.4.2.3.1 **Additional Damage Observed in A-Mill**

Once in the ducting of the A-Mill, the flame propagation is shown to have spread through additional ducting in the photos below. Starting with the first floor of the A-Mill, additional ducts were observed to have experienced an internal overpressure and soot deposition from the grain fuel as shown in the separated blind in Figure 93.

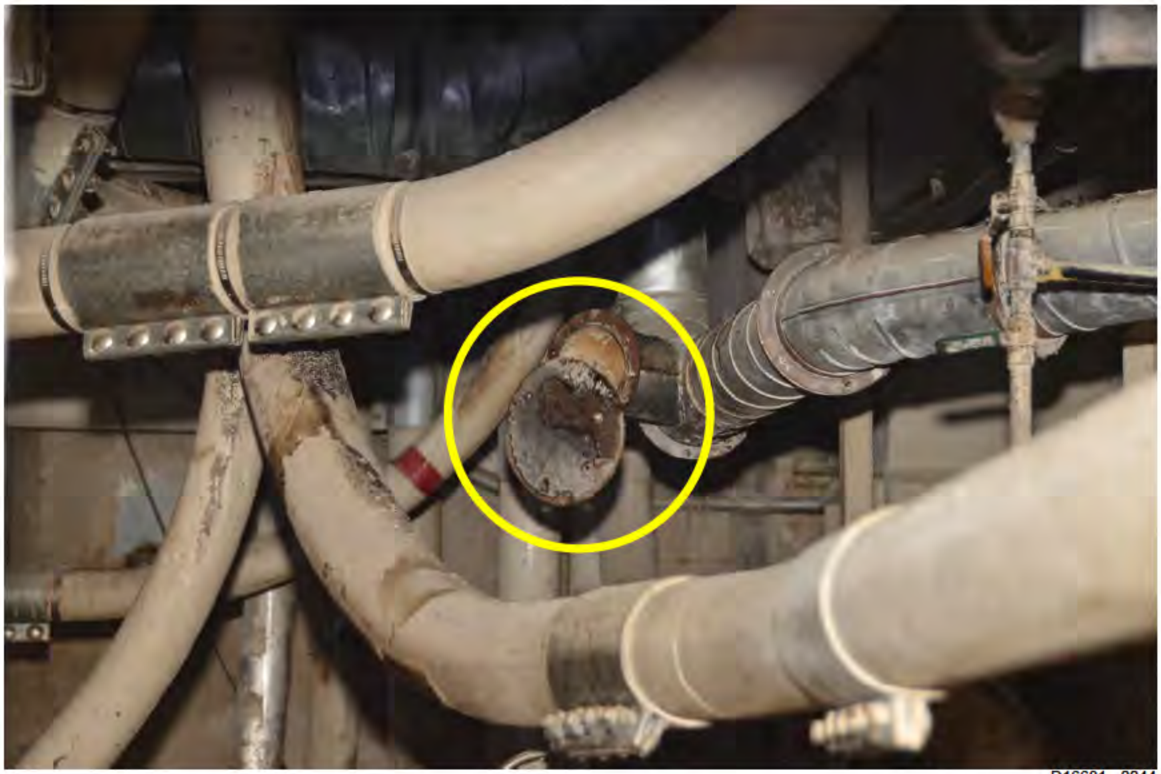


Figure 93. Post-incident view of a separated flange in A1.

In addition to the internal overpressure experienced in the 6-section sifter on the 3rd floor of the A-Mill shown in Figure 90, a collapsed duct was also observed, as seen in Figure 94. Ducts have been known to collapse after a propagating explosion due to a negative pressure (vacuum) that often follows the overpressure wave.[206]

[206] Cox B., Hietala D., Ogle R. (2021). Dust explosions and collapsed ductwork. J. Loss. Prev. Process Ind. 69, 104350.

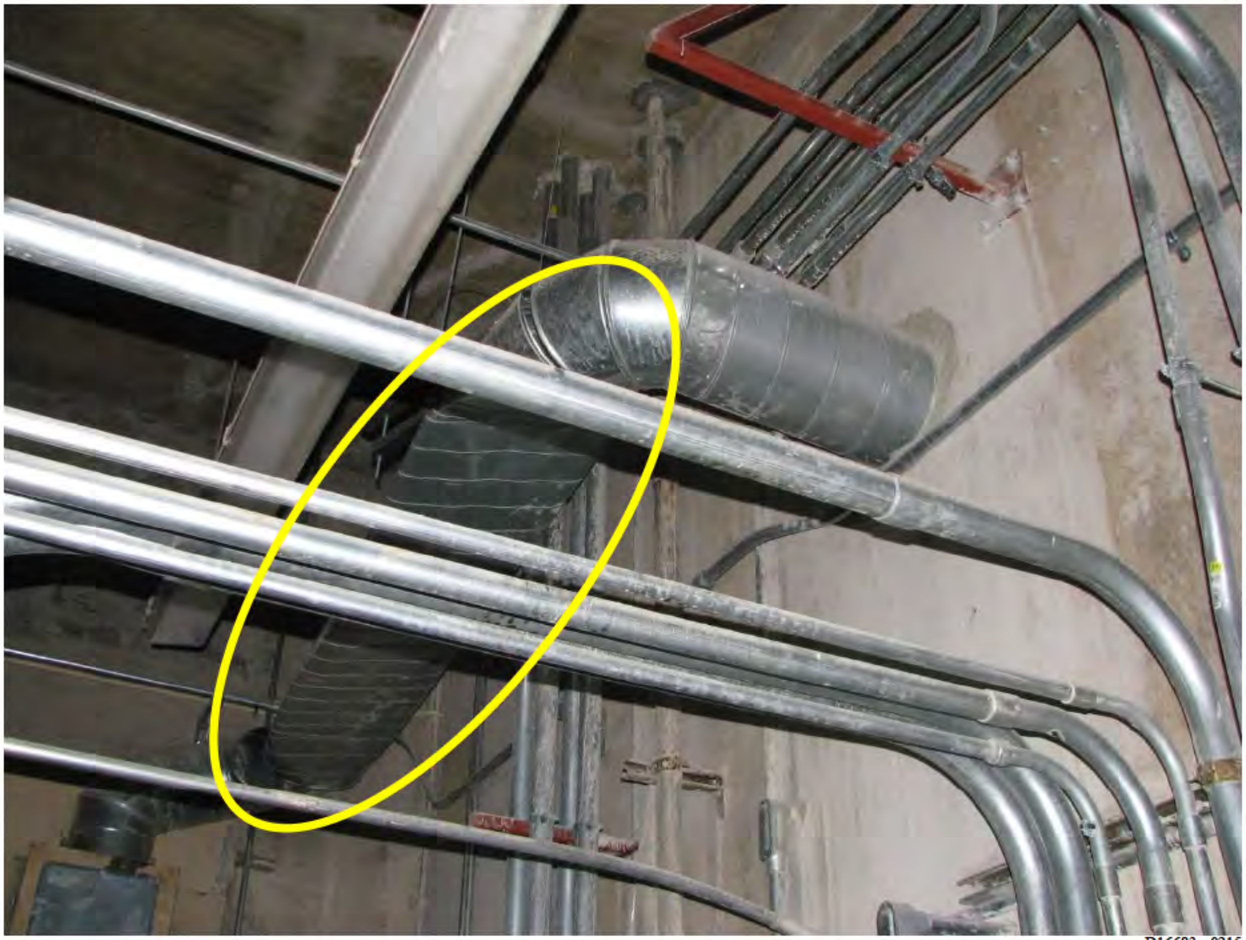


Figure 94. Post-incident view of collapsed duct from internal overpressure on the 3rd floor of the A-Mill.

Another apparently collapsed duct was also observed on the 4th floor of the A-Mill as shown in Figure 95. Additional separated ducting was also observed on the 4th floor of the A-Mill, shown in Figure 96.

D16681 - 0382

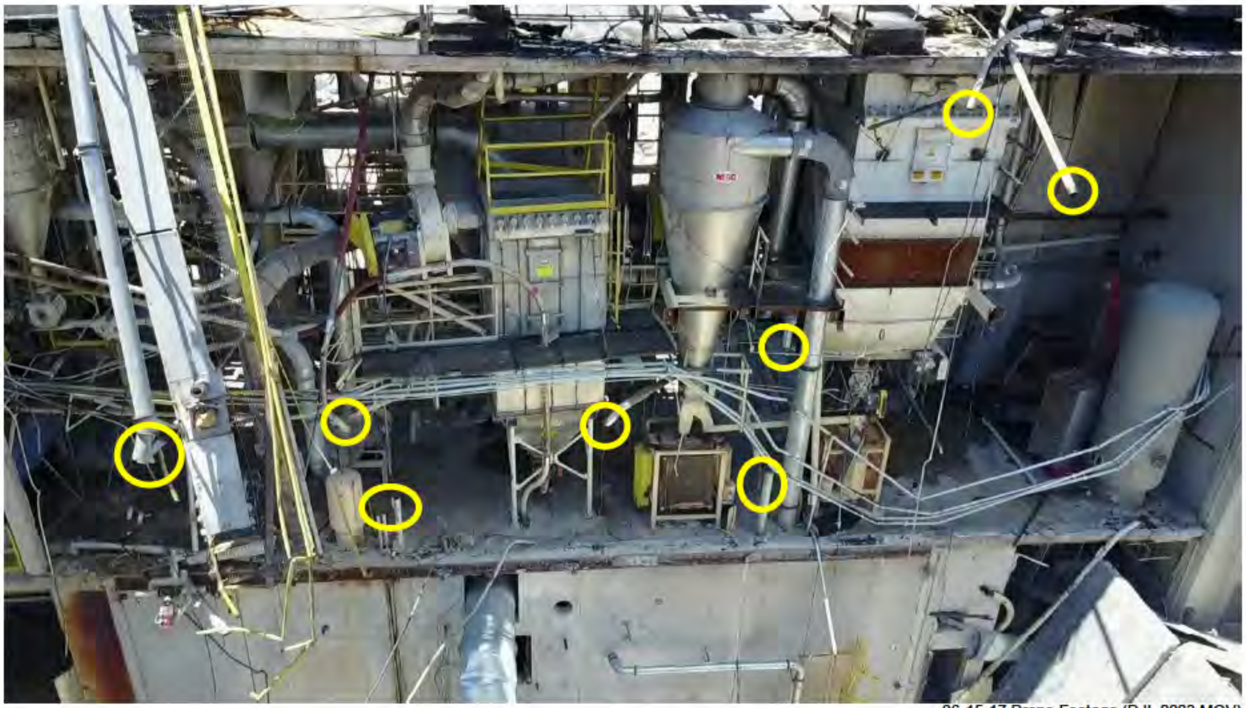
Figure 95. Post-incident view of flattened duct from internal overpressure on the 4th floor of the A-Mill.

D16681 - 0399 (left), D16681 - 0404 (right)

Figure 96. Post-incident view of additional separated ducting on the 4th floor of the A-Mill.

3.4.2.4 Dry Grit Filter to B-Mill

While the Dry Grit Filter does not appear to have been connected directly to equipment in the Bran System in the B-Mill, it is connected to other systems inside the B-Mill such as the Government System,[207] PPS fractionation system,[208,209] and Grit Drying System.[210] Few photographs of the fourth floor of the B-Mill exist because it was considered unsafe for long-term occupation, but multiple ducts separated over the course of the incident, as observed in Figure 97.



06-15-17 Drone Footage (DJI_0003 MOV)

Figure 97. Post-incident drone footage of the 4th floor of the B-Mill.

3.5 Opinion 5: Fires and explosions were fueled by other material

Opinion 5: *Fires and explosions fueled by other material also occurred throughout the facility. For example, a cylinder containing liquefied petroleum gas (LP-gas) exploded within the Pack area, contributing to the damage in this portion of the mill. A transformer was also damaged due to a concrete wall panel that fell from the B-Mill, resulting in a fire and/or explosion fueled by transformer oil.*

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[207] REF-MILL-ENG-8601-01 Gov Packaging System Process Flow S#01.pdf

[208] REF-MILL-ENG-3401-01Fractionation System S#1.pdf

[209] REF-MILL-ENG-3402-01Fractionation System S#2.pdf

[210] REF-MILL-ENG-4601-01 Grit Drying System.pdf

3.5.1 LP-gas Cylinder

During the incident, the LP-gas cylinder (PA EFI #49) associated with a fork truck (PA EFI #36) exploded in the Pack area. The fork truck was found very near the doorway into the Pack area from the stairwell between the A-mill and the B-mill. The LP-gas cylinder was apparently recovered further north near debris adjacent to the stairwell to the Pack mezzanine (see Figure 101).[211] This is in the vicinity of the location where one of the decedents was found.[212]

[211] The LP-gas cylinder was tagged as PA EFI #49, immediately after a fan (PA EFI #47) and the Pack line 2 scale filler and hanger (PA EFI #48), and before an inclined conveyor associated with the Pack line (PA EFI #50).

[212] See DM0086642_IMG_8337, showing both the fan (PA EFI #47) and the conveyor (PA EFI #50), and DM0086643_IMG_8338, showing the decedent's location under stairs near the two tagged items.

DM0086636_ MG_8328, DM0086637_IMG_8330

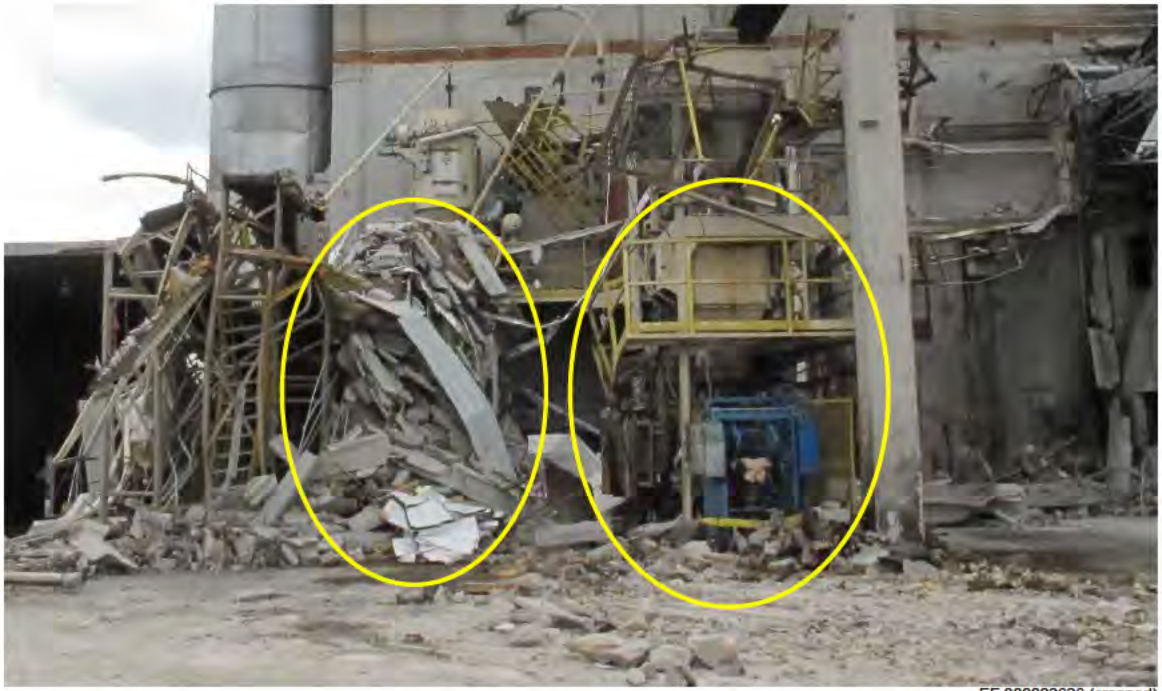
Figure 98. Photographs of the fork truck located in the Pack area most likely associated with the LP-gas explosion. The location of the fork truck is difficult to discern in the first photograph, due to lighting, so the front-left wheel has been circled in dashed yellow in each.

EFI000001628, D16767 – 00339

Figure 99. Photographs of the fork truck prior to recovery from the Pack area (left) and post recovery (right).

EFI000002689 (left) EF 000002690 (right)

Figure 100. The LP-gas cylinder most likely associated with the fork truck



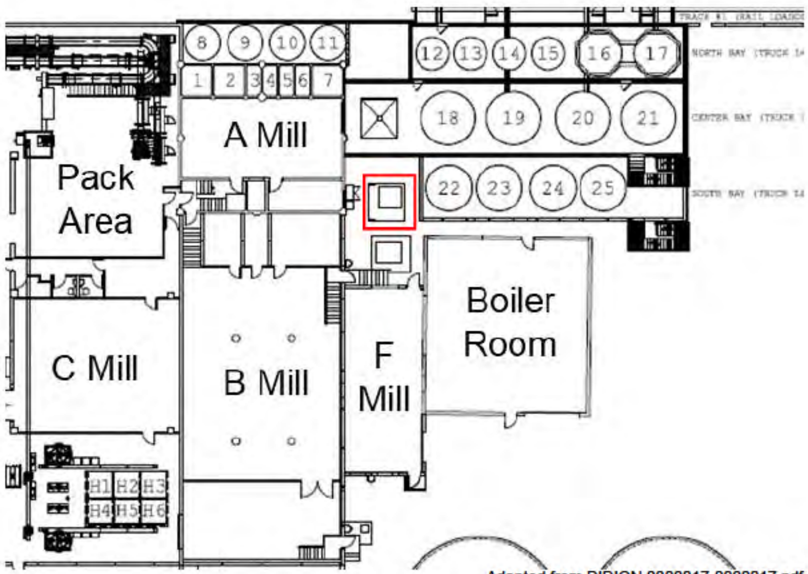
EF 000002626 (cropped)

Figure 101. The LP-gas cylinder was apparently recovered further north near debris adjacent to the stairwell to the Pack mezzanine, in the vicinity of a fan (PA EFI #47), the Pack line 2 scale filler and hanger (PA EFI #48), and an inclined conveyor associated with the Pack line (PA EFI #50). The fan and conveyor were located beneath the pile of debris circled on the left, and the location of the scale filler and hanger is circled on the right. One of the decedents was found under the debris shown on the left. See DM0086642_IMG_8337, showing both the fan and the conveyor, and DM0086643_IMG_8338, showing the decedent's as-found location under the stairwell to the mezzanine.

3.5.2 Transformer

A transformer was damaged by a panel that most likely fell from the B-Mill, resulting in a fire involving the mineral oil contents of the transformer. Burning liquid erupted and/or poured from the transformer into the Center Bay of the Truck Loadout area. The spalled concrete on the walls in the center bay is consistent with the rapid and intense heat development from an ignitable liquid fire.[213] The soot development on the walls and ceiling is consistent with a prolonged fire.

[213] NFPA 921: Guide for Fire and Explosion Investigations, 2021. § 6.3.14.



Adapted from DIDION 0000017-0000017.pdf

Figure 102. The transformer that was damaged in the explosion was located in a courtyard between the mill buildings and truck loading area, shown in red.

D16681 - 0074

Figure 103. Transformer that was impacted by a panel that most likely fell from the B-Mill, resulting in a fire involving transformer oil. Yellow arrows indicate the locations of the panel and transformer.

D16683 - 0025

Figure 104. Center Bay looking at the doorway to the South Bay with the doorway to the transformer on the right. The spalled concrete walls, e.g., where the yellow circle encloses, are consistent with rapid and intense heat development from an ignitable liquid fire.[214]

[214] NFPA 921: Guide for Fire and Explosion Investigations, 2021. § 6.3.14.

Client-supplied image from drone on October 2, 2017, DJI_0348

Figure 105. An egress pathway from B1 led up the internal North East stairs and back down into the transformer courtyard shown above, after the debris to the east of the B-Mill was cleared post-incident. From the transformer courtyard, the Center Bay was accessible through the double doorway in front of the transformer shown in Figure 103. The southern edge of this transformer can be seen in the far right, circled in yellow.

4 Rebuttal of Mr. Cholin and Mr. Osborn

4.1 Opinion 6: Rebuttal of Mr. Cholin #1

Opinion 6: *Mr. Cholin's determination regarding the cause of propagation of the explosion throughout the facility is erroneous. Mr. Cholin's report stated that, "All of the evidence we have been able to study supports the conclusion that all of the injuries were either the direct consequence of the deflagration fueled by accumulated dust or the consequence of structural failure caused by those dust deflagrations."*[215] *However, Mr. Cholin's analysis is based on circular reasoning that lacks substantiation. In summary, he concludes that accumulated dust must have been present and must have been the cause of the event because he otherwise lacks the ability to explain it. However, internal propagation of interconnected equipment is a known phenomenon and the in-process material was a viable fuel. The evidence shows that material originating inside equipment/ducts and material ejected from equipment/ducts was the primary source of fuel during the incident, with respect to both the primary and the subsequent explosions. In fact, deflagrations must have propagated internally before any external explosions were observed because their ignition occurred internal to equipment. Additionally, the only viable explanation for the Dry Grit Filter explosion observed shortly after the B1 explosion is due to internal propagation. Yet Mr. Cholin failed to consider the role of internal propagation. Thus, his conclusions regarding the role of fugitive dust in this event are not substantiated.*

Mr. Cholin constructs his hypothesis based upon an assumption that all relevant explosions must occur exterior to the equipment, in the room compartments of the Didion Milling facility. He uses this assumption to conclude that sufficient fuel to propagate the explosion must have been present, because absent this fuel, no such explosion could occur. As a result, his conclusions are mere tautology. Because Mr. Cholin restricts propagation to the spaces outside of equipment, his reasoning concludes that there must have been sufficient fuel outside of equipment for the explosion to propagate. He further ignores material ejected from equipment as the event progressed, so his reasoning concludes that this fuel must have been present prior to the incident in the form of fugitive dust.

However, his hypothesis ignores the primary mechanism by which material is normally conveyed around the facility: processing equipment and dust collectors interconnected by ductwork. The material within this equipment and ductwork was mostly combustible dust at or above explosible concentrations, as evidenced by the signs of propagation throughout the facility, described above with extensive photographic documentation above in Section 3.

As a result of this flawed analysis, Mr. Cholin incorrectly adopted the hypothesis he set out to prove. At best, he should have concluded that the role of fugitive dust in the explosion in B1 and the propagation throughout the facility is "undetermined."

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[215] Expert Report of Mr. Cholin, January 21, 2023. p. 176.

However, much of Mr. Cholin's analysis regarding the presence and distribution of fugitive dust appears to be based upon generalization of historical photographs of upsets and worst-case conditions. For example, Mr. Cholin presents two photos of the B1 Coarse Grinder Filter 26 days before the incident and three photos of the small, GM-80 Bauermeister Mill from 15 days before the incident as the sole pieces of direct evidence to substantiate the claim of fugitive dust in B1.[216] He is either unaware of or chose to ignore witness testimony from one of the packers[217] indicating that B-1 was cleaned for several hours on May 31, 2017, about five hours before the incident occurred (Section 2.6.4).

Mr. Cholin's analysis also ignores the fact that the eyewitness testimony—particularly that of [redacted]—concerning the amount of suspended fugitive dust present early in the sequence of events does not support the conclusion that fugitive dust was the primary cause of fire/explosion propagation. [redacted] recalled the initial flame erupting from the SBM. [218,219] When that flame sucked back into the SBM, [redacted] testified that dust began trickling down from the conduit and pipes that run across the ceiling of B1.[220] Upon seeing the dust begin to fall, [redacted] turned his head to look at Mr. Alva, who was already looking at [redacted], and they looked at each other in shock. [redacted] testified, "[T]hen all of a sudden, the flame [from the SBM] shoots back out again, and I look at [Mr. Alva], and I just do that, signal him out, and it's like, yup, and we both ran."

The ability of [redacted] and Mr. Alva to see other from more than two meters apart, make eye contact, communicate by facial expression and hand signal, while the dust is falling from the piping and ducting above, demonstrates that the amount of airborne fugitive dust within B1 when the second flame erupted from the SBM was nowhere near the minimum explosible concentration (MEC), discussed above in Section 2.4.

Furthermore, Mr. Cholin asserts of his alleged mechanism:[221]

> *Thus, the observed flame transitioned into a deflagration shortly after the witnesses had begun their escape. It is probable that the incident progressed through the following process in a very short elapsed time, probably on the order of less than one second.*

However, this timing would not have allowed either [redacted] or Mr. Alva to escape, especially since this was the *second* such flame.

There is minimal physical evidence of fugitive dust present at the time of the explosion, primarily limited to the A-Mill and B-Mill air shafts. Mr. Cholin offers no evidence that these air shafts were connected, despite his assertion that the "deflagration propagated via the [B-

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[216] Expert Report of Mr. Cholin, January 21, 2023. pp. 36-38.

[217] U.S. Chemical Safety and Hazard Investigations Board Interview of [redacted]. June 15, 2017. pp. 3, 13-16, 18, 29-30. GJ_CSB_0004501, GJ_CSB_0004511-4, GJ_CSB_0004516, GJ_CSB_0004527-8.

[218] Wisconsin Department of Justice DCI Interview of [redacted]. June 14, 2017. p. 3. WDOJ_000380.

[219] Deposition Transcript of [redacted], May 13, 2021. p. 136.

[220] Deposition Transcript of [redacted], May 13, 2021. pp. 136-137.

[221] Expert Report of Mr. Cholin, January 21, 2023. p. 145.

Mill] air shaft to the A-Mill and vertically to the upper levels of both A-Mill and B-Mill" and that the air shaft "was shared with the adjacent A-Mill."[222]

Mr. Cholin further asserts that "Calculations show that the participation of dust accumulations in the subsequent building compartments were necessary to extend the deflagration flame front."[223] However, he provided no analysis or consideration regarding how he ruled out propagation through equipment or the presence of ejected product from equipment other than the SBM, despite all of the evidence of such phenomena.

Notably, Mr. Cholin offers no explanation for the explosion of the Dry Grit Filter. Such an explosion required internal propagation to occur, as the Dry Grit Filter was located outside. According to the testimony of [redacted], the explosion occurred very quickly after the B1 explosion, evidencing that internal propagation occurred rapidly to locations distant from B1.

For these reasons, Mr. Cholin's determination is erroneous.

4.2 Opinion 7: Rebuttal of Mr. Cholin #2

Opinion 7: *Mr. Cholin's analysis of "alternative scenarios identified by others as possible causes"[224] fails to prove or disprove anything about the propagation of the explosion throughout the facility. Instead, these hypotheses are constructed as strawman arguments addressed with perfunctory and selectively applied analyses that fail to disprove that any of the underlying mechanisms were key factors in the complex, dynamic event. The evidence shows that key mechanisms that Mr. Cholin ignored, dismissed, and/or erroneously analyzed contributed to this complex event.*

In four of the last pages of his 184-page report, Mr. Cholin presents four alternative scenarios, which he reports were "identified by others."[225] Although he fails to cite the "others" that he references, these hypotheses appear to be nothing more than strawman arguments, offered to further bolster his hypothesis that fugitive dust was the sole source of fuel for the May 31, 2017, explosion. These hypotheses are identified by Mr. Cholin as follows:

- "Conveying Duct Rupture Hypothesis"
- "Discharge of Dust from the South Bauermeister Gap Mill"
- "Propane Tank Rupture and Ignition Hypothesis"
- "Natural Gas Line Supply to the Mill"

222 Expert Report of Mr. Cholin, January 21, 2023. pp. 3, 33.

223 Expert Report of Mr. Cholin, January 21, 2023. p. 3.

224 Expert Report of Mr. Cholin, January 21, 2023. p. 180.

225 Expert Report of Mr. Cholin, January 21, 2023. pp. 180-183.

4.2.1 Conveying Duct Rupture Hypothesis

Mr. Cholin's analysis regarding ruptured conveying lines[226] fails in light of specific details of the incident and the facility. For example, the Cholin report identifies criteria that he alleges were missing from evidence for this incident:

1. The four (4) requisite conditions for deflagration:[227]
    a. Deflagrable dust
    b. Suspension in air
    c. Sufficient concentration
    d. Competent ignition source
2. The scene documentation would have to include the evidence of a ruptured line and the evidence of the ejection of the contents into the facility interior.
3. Process data would have to show that the specific line alleged to be the cause of the dust release was operating under positive pressure at the time of this incident.

Regarding the four requisite conditions for deflagration, it is clear that the explosion originated in the SBM in B1, as discussed in Section 3.1 and in Mr. Cholin's report.[228] The conditions of deflagrable dust, suspension in air, sufficient concentration, and competent ignition source were all met within the SBM. The ensuing propagating pressure waves and flame front provided the means of first suspending dust and then igniting dust. It is unclear why Mr. Cholin indicates that "[t]he scene documentation would have to identify the ignition source,"[229] when the relevant ignition source (the first flame identified by [redacted]) was clearly documented by Mr. Dodge's testimony (Section 2.6.4) and acknowledged by Mr. Cholin in his report.[230] This first flame represented a sufficient ignition source and necessarily would have traveled outward from the area of origin, the South Bauermeister. Furthermore, numerous ducts and pipes were identified in Section 3.2 that contained deflagrable dust (as many of these were material-carrying conduits by design).

Regarding Mr. Cholin's second point about scene documentation, Exponent's report provides abundant evidence of ruptured lines and ejection of contents that occurred as a result of the explosion that propagated internally, throughout the facility. Some equipment and ducts showed no apparent damage,[231] despite internal propagation (i.e., ducting that had their caps blown off, shown in many figures throughout Section 3.2, 3.3, and 3.4), whereas other equipment and ducts were compromised and ejected their contents (seen in photos in Section 3.3). Ignition occurred in many of these release events. At least three operational material conveyance lines separated

[226] Expert Report of Mr. Cholin, January 21, 2023. pp. 180-181.

[227] Expert Report of Mr. Cholin, January 21, 2023. pp. 126 and 180.

[228] Expert Report of Mr. Cholin, January 21, 2023. p. 3.

[229] Expert Report of Mr. Cholin, January 21, 2023. p. 180.

[230] Expert Report of Mr. Cholin, January 21, 2023. p. 76.

[231] Note, this is not a surprise, as the internal overpressure required to rupture ducts is usually very high, c.f., Cox B., Hietala D., Ogle R. (2021). Dust explosions and collapsed ductwork. J. Loss. Prev. Process Ind. 69, 104350.

in B1 during the incident (seen in photos in Section 0 and 3.3.1.1). At least two of these separations due to internal propagation were associated with the Bauermeisters (as shown in figures in Section 0).

Mr. Cholin's third point regarding process data and operation under positive pressure is simply inaccurate and reveals a lack of knowledge and understanding of the processes performed at Didion Milling and the evidence collected after the explosion. There are multiple ways in which material was released forcefully over the progression of the incident. Portions of the Bran System and most other processes relied upon gravity-driven flow, including the BMs at the center of this investigation. The separation of a duct at the ceiling level allowed material to be ejected into the B-Mill, most likely creating an ignitable mixture. The separation of the NBM inlet would have resulted in an ongoing ejection of material at or near full feed rate until the material intended for delivery to the NBM was depleted. Furthermore, [redacted] observed two deflagration events that resulted in the pressurization of the SBM air-intake suction line. Obviously, burning material was ejected from this line, despite it normally being under negative pressure (Section 2.6.4).

Mr. Cholin acknowledges that an internally propagating pressure wave from the SBM traveled through the SBM Cyclone and reached the SBM in B1.[232] He alleges that the burn patterns around the fan flange represent evidence of "flame quenching" and that "flame was able to exit the dust collection system at this location." He further alleges "the concentration of dust in the duct is not sufficient to propagate deflagration." However, Exponent has demonstrated that these allegations are false. As has been extensively documented in Sections 3.2, 3.3, and 3.4, there are extensive inspection photos post-incident that provide evidence of internal propagation from which the flame/deflagration spread through the internal ducts and equipment leaving popped off caps, burned product ejected from over pressured caps on ducts, collapsed ducts, and clear propagation pathways identified.

There is clear evidence that flame entered the Government Line in B1 (see Figure 75, Figure 76, and Figure 77). This is the most likely pathway for the flame that propagated to the Dry Grit Filter within seconds of the B1 explosion, according to [redacted] account of the incident.[233,234] This critical witness observation is omitted entirely from Mr. Cholin's 184-page report, and Mr. Cholin offers no explanation about how the explosion in the Dry Grit Filter could have occurred via the propagation mechanism postulated in his report.

Another point Mr. Cholin incorrectly asserts in support of his analysis is as follows:[235]

> *It is well known that when a dust deflagration is confined to an elongated enclosure, such as a duct, that the flame front accelerates until there is a transition to detonation.*

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[232] Expert Report of Mr. Cholin, January 21, 2023. pp. 99, 180.

[233] Deposition Transcript of [redacted], May 13, 2021. pp. 146-147.

[234] U.S. Chemical Safety and Hazard Investigations Board Interview of [redacted]. July 11, 2017. p. 11. GJ_CSB_0005692.

[235] Expert Report of Mr. Cholin, January 21, 2023. p. 180.

> *When this occurs, the rupture of the confining enclosure transitions from elastic yield to brittle yield. No evidence of brittle yield failure was documented.*

Mr. Cholin's reference does not support his assertion that a detonation-to-deflagration transition (DDT) would be expected. In fact, it merely states that a detonation "may develop in ducts of large L/D via enhanced combustion due to flow-generated turbulence."[236] In fact, this phenomenon is only known to occur for corn products in ducts that are very long relative to their diameter (e.g., L/D ~ 100 or more).[237] For example, a DDT was observed with cornstarch in a 12"-tube approximately 120 feet in length, which is less than the height of the B-Mill building.[238] In the same study, DDT was not achieved in a 4" tube without significantly increasing the starting pressure. Duct sizes vary throughout Didion's milling processes, from around 4" to as large as 36". In the study, Aluminum dust also did not achieve DDT in the smaller tube size. Mr. Cholin is incorrect when he asserts that the absence of evidence of a detonation is dispositive that internal propagation did not occur. In fact, a detonation would not be expected to occur as a result of this incident.

As shown in the Engineering Analysis sections above, photographic evidence of popped off caps, burned product ejected from over pressured caps on ducts, and collapsed ducts demonstrates that internal propagation occurred over long distances throughout the mill (e.g., from B1 to the Dry Grit Filter) and played a central role in the development of this complex incident.

4.2.2 Discharge of Dust from the South Bauermeister Gap Mill

Mr. Cholin offers two arguments against the discharge of dust from the SBM hypothesis, each of which is deeply flawed.

First, he asserts that a cloud of sufficient dust to cause the explosion originating from the SBM would necessarily "have appeared to extend from floor to ceiling" and would be totally light-obscuring and opaque to the witnesses to be explosive as observed in Figure 3.[239] In this statement, he cites the wrong prior section of his report (8.8.2 vs his citation of 8.7.2).[240] In Section 8.8.2, he ultimately concludes that a 45 m^3 cloud at a concentration of 500 g/m^3 would be sufficient to achieve the observed pressure effects, but in his consideration of this alternative hypothesis in Section 10.2, he stated it would require 90 m^3 at the same concentration. Correcting these errors, his argument appears to be that the same mass and concentration of material would be necessary as is used in his preferred hypothesis, but the shape would be different. This is an unsupported assertion.

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236 Eckhoff, R. Dust explosions in the process industries. 3rd Ed., p. 367.

237 Ogle R. (2017). Dust explosion dynamics. Elsevier. pp. 548-550.

238 DIDION0002082.pdf

239 Expert Report of Mr. Cholin, January 21, 2023. p. 181.

240 Expert Report of Mr. Cholin, January 21, 2023. p. 134.

Further, he alleges that insufficient fuel would have been available within the SBM to fuel the explosion—which he states is 22.5 kg of material occupying 0.066 m^3.[241] However, his analysis neglects the gravity-driven flow of material into the SBM, as described in Section 2.5.2, and fails to acknowledge that dust was *necessarily* discharged from the SBM in the form of the burning dust that fed the flames observed by Mr. Dodge (Section 2.6.4). The overheating material in the SBM (Figure 23) clearly indicates that the flow of material was slower than intended, suggesting a backup of material in the feed to the SBM. Once the material was able to flow, a higher material flowrate than normal would be expected until the backup could clear itself through gravity.

Mr. Cholin states that approximately 0.066 m^3 or about 12 feet of 6-inch duct would need to be filled with product to provide the fuel necessary for the explosion in B1. The combined volume of the two bran polishers (Figure 106) and the feed lines between them and the SBM would provide more than the amount that Mr. Cholin alleged was necessary. Furthermore, material would begin flowing rapidly as soon as an outlet pathway could be established (e.g., a duct is separated allowing unrestricted flow of material). The separated duct on the NBM inlet flowed directly from the 6-Section Sifter on 4B, which also would have provided considerably more material than would be contained in "12 feet of 6-inch duct."

[241] Expert Report of Mr. Cholin, January 21, 2023. p. 182.

D16680 – 0602 (top), D16680 – 0627 (bottom)

Figure 106. Photographs of one of two Bran Polishers immediately upstream of the South Bauermeister. Product clearly ejected and/or overflowed from the feed to each Bran Polisher.

4.2.3 Propane Tank Rupture and Ignition Hypothesis

As described above in Opinion 5 in Section 3.5.1, based on both the physical evidence and witness statements, an LP-gas cylinder ruptured in the Pack area during the incident. The potential contribution of this event is beyond the scope of my report, but the LP-gas cylinder

was recovered around the same time and location as evidence that can be seen in photographs in the vicinity of one of the decedents.[242]

4.2.4 Natural Gas Line Supply to the Mill

Evidence pointing directly toward natural gas as a contributor to the incident has not been identified to date, but natural gas was at multiple locations within the facility. While there were no contemporaneous reports of odors associated with natural gas during the incident, many of the reported explosion events were not directly observed. Odors associated with natural gas were observed during subsequent inspections of the site and forced at least one evacuation of the mill buildings during post-incident activities.

4.3 Opinion 8: Rebuttal of Mr. Osborn

Opinion 8: *Mr. Osborn's opinions regarding the performance of Didion's dust collection systems allege that combustible dust would be present at all times within the Torit and Dry Grit Filter dust collection headers. Indeed, even in the best performing dust collection system, there will inevitably be dust (fuel) present in the dust collection system during operation. Thus, his opinions are irrelevant to the propagation of the incident, but nonetheless underscore the presence of fuel in the dust collection system that was ignored by Mr. Cholin in his analysis of the propagation of the explosion. In fact, neither Mr. Osborn nor Mr. Cholin opine on propagation of the explosion through dust collection systems, further evidencing their disregard for material inside equipment/ducts and underscoring the deficiencies in their opinions.*

The presence of combustible dust in a dust collection system is expected during operation. The purpose of the dust collection system is to collect fine particulates. Direct evidence of propagation through the dust collection systems at the mill is shown in Figure 36 and Figure 69 for the Torit Filter, in Figure 86 for the Dry Grit Filter, and in multiple other images throughout the mill, e.g., those shown in Sections 3.3 and 3.4. Both of these systems were critical in the distribution of damage throughout the facility, as the Torit was located immediately downstream of the Bauermeister cyclones, and showed evidence of the propagation of burning material throughout the Bran System as well as to other areas of the mill, as discussed above. The Dry Grit Filter holds a similar importance, as witnesses described that the Dry Grit Filter exploded "3 to 5 seconds" after the B1 room explosion.[243,244,245] As discussed in Opinion 4 and Opinion 6 and shown in Figure 81, the only viable pathway to the Dry Grit Filter was through internal propagation.

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242 See DM0086642_IMG_8337, showing both the fan (PA EFI #47) and the conveyor (PA EFI #50), and DM0086643_IMG_8338, showing the decedent's location under stairs near the two tagged items.

243 Note: the Dry Grit Filter is at times also referred to as a Drager filter.

244 Deposition Transcript of [redacted], May 13, 2021. pp. 146-147.

245 U.S. Chemical Safety and Hazard Investigations Board Interview of [redacted]. July 11, 2017. p. 11. GJ_CSB_0005692.

Mr. Osborn asserts that the designs of the Torit and the Dry Grit dust collection systems would result in “significant material accumulations” in the dust collection headers.[246] While I do not concede to Mr. Osborn’s allegations regarding the design of the dust collection systems, his assertions regarding the potential presence of additional material deposits in these ducts would further support the need to consider this pathway relative to internal propagation of the explosion throughout the facility.

Yet neither Mr. Osborn nor Mr. Cholin opine on propagation of the explosion through dust collection systems, further evidencing their disregard for material inside equipment/ducts and underscoring the deficiencies in their opinions.

[246] Expert Report of Osborn, undated. pp. 30-31.

Appendix A

Curriculum Vitae

Brenton L. Cox, Ph.D., P.E., CFEI

Exponent® Engineering & Scientific Consulting

Brenton L. Cox, Ph.D., P.E., CFEI

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Professional Profile

Dr. Cox specializes in the investigation, analysis, and prevention of incidents involving fires, explosions, and chemical releases. He has helped clients solve technical challenges associated with potentially flammable and/or reactive materials in the chemical process industry, agricultural and agro-industrial facilities, mining and metal processing, pulp and paper manufacturing, hazardous waste treatment and disposal facilities, and consumer products.

Dr. Cox applies his experience and expertise in chemical engineering, risk management, and incident investigation to advise clients on issues associated with potentially hazardous materials, particularly flammable liquids and vapors and combustible dust. He has consulted with clients on matters related to Process Safety Management (PSM), including the OSHA PSM standard (29 CFR 1910.119) and the Canadian PSM standard (CSA-Z767-17). Similarly, he has helped clients manage risks addressed in the National Fire Protection Association (NFPA) publications associated with combustible dust.

Dr. Cox has conducted risk studies for industrial processes and consumer products. He is a trained process hazard analysis (PHA) facilitator whose consulting services have involved hazard identification (HAZID), checklist, what-if, hazard and operability (HAZOP) studies, quantitative risk assessment (QRA), failure modes and effects analysis (FMEA), and consequence modeling. He has also been trained in advanced emergency relief design through a course developed by the Design Institute for Emergency Relief Systems (DIERS), of which he is a member. He is a member of the technical committee for NFPA 214: the Standard Water-Cooling Towers.

Dr. Cox is an active leader and participant in the process safety community, regularly contributing to conferences and technical publications. He has presented papers at the Global Congress on Process Safety (GCPS), the Institution of Chemical Engineers (IChemE) Hazards Conference, and the Mary K O'Connor Process Safety Center International Symposium. In 2019, he served as chair of the Process Safety Management Mentoring Forum at the GCPS and co-authored a chapter on Risk Assessment to appear in Dust Explosions, a volume of Elsevier's series on Methods in Chemical Process Safety.

Dr. Cox's doctoral thesis examined the process dynamics, heat transfer, and fluid mechanics of a single-stage metal casting process. The focus of his research was the prediction and control of process instabilities affecting material thickness. This study included lab-scale casting of various aluminum alloys and theoretical modeling of transport phenomena and interfacial stability. Prior to his thesis research, Dr. Cox assisted in studies of bacterial growth kinetics, the mechanics and stability of powder flow, and the use of siloxane polymer coatings on wine corks to prevent corkage. His laboratory experience includes metal casting, bench-scale biological reactor design and operation, and the use of a variety of analytical equipment, including high-performance liquid chromatography (HPLC), differential scanning calorimetry (DSC), thermogravimetric analysis (TGA), fluorescent/ultraviolet/visible spectroscopy, and optical profilometry. He has captured and analyzed high-speed images at rates up to 50,000 frames-per-second.

Dr. Cox also has experience operating mathematical and process design software, such as Matlab, Mathematica, HYSYS, and PHAST.

Academic Credentials & Professional Honors

Ph.D., Chemical Engineering, Cornell University, 2011

B.S., Chemical Engineering, University of Florida, *magna cum laude*, 2005

Licenses and Certifications

Licensed Professional Engineer, Illinois, #062-066182

Licensed Professional Engineer, Wisconsin, #46956-6

Licensed Professional Engineer, Indiana, PE12100315

Credential in Grain Operations Management, Grain Elevator and Processing Society (GEAPS), Certification #11989

Process Hazard Analysis (PHA) for Team Leaders

Certified Fire and Explosion Investigator (CFEI) in accordance with the National Association of Fire Investigators (NAFI) National Certification Board per NFPA 921 Section 13.6.5.

40-Hour Hazardous Waste Operations and Emergency Response (HAZWOPER) Training

Professional Affiliations

American Institute of Chemical Engineers — AIChE (member)

National Association of Fire Investigators — NAFI (member)

National Fire Protection Association — NFPA (member)

Principal Member: Technical Committee on Water-Cooling Towers (WAC-AAA), NFPA 214: Standard on Water-Cooling Towers, National Fire Protection Association.

Design Institute for Emergency Relief Systems — DIERS (member)

Grain Elevator and Processing Society — GEAPS (member)

Publications

Dee, SJ, Cox, BL, Ogle, RA, and Walters, MS. Deciding Between Short-Term and Long-Term Solutions for Aging Infrastructure. Chemical Engineering Progress, 2021; August: 20-27.

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Cox BL, Carpenter AR, Ogle RA. Lessons learned from case studies of hazardous waste/chemical reactivity incidents. Process Safety Progress 2014; 33(4):395-398.Cox BL, Dee SJ, Hart RJ, Morrison DR. Development of a steel component combustion model for fires involving pure oxygen systems. Process Safety Progress 2014; 33(3):299-304.

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Cox BL. Operating rooms as wet/dry locations risk assessment. Report for the Fire Protection Research Foundation, August 2012.

Cox BL, Steen PH. Finite-amplitude dynamics of coupled cylindrical menisci. Journal of Colloid and Interface Science 2011; 362(1):215-220.

Conference Proceedings and Presentations

Cox BL, Walters MS, Dee SJ, Ogle RA. Taking Action on Your DHA Action Items. 17th Global Congress on Process Safety, Virtual Meeting, April 18-23, 2021.

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Garner S, Cox B, Bishop J, Fecke M. Electrical Area Zoning: Its role in a risk-based process safety program for combustible dusts. Institution of Chemical Engineers (UK), Hazards 27, Birmingham, UK, May 10-12, 2017.

Morrison DR, Cox BL. Investigating chemical process incidents & near misses, Short Course. 13th Global Congress on Process Safety, San Antonio, Texas, March 26, 2017.

Cox BL, Dee SJ, Ogle RA. When the fail open valve fails closed: lessons from investigating the "impossible." American Institute of Chemical Engineers, 2017 Spring National Meeting, 13th Global Congress on Process Safety, San Antonio, TX, March 26-29, 2017.

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Morrison DR, Cox B. Investigating chemical process incidents & near misses, Short Course. 12th Global Congress on Process Safety, Houston, Texas, April 10, 2016.

Morrison, DR, Kumar V, Dee SJ, Cox BL, Al-Shamary M, Al-Qabandi A. Fire from the cascading failure of an oxygen supply system. American Institute of Chemical Engineers, 2015 Spring National Meeting, 11th Global Congress on Process Safety, Austin, TX, April 27-April 29, 2015.

Cox BL, Dee SJ, Carpenter, AR, Ogle RA. Hazards inherent to batch processing: Lessons learned from case studies. American Institute of Chemical Engineers, 2015 Midwest Regional Conference, Chicago, IL, March 13-14, 2015

Ogle RA, Cox BL, Dee SJ. Scaling analysis for confined dust flame propagation. American Institute of Chemical Engineers, 2015 Midwest Regional Conference, Chicago, IL, March 13-14, 2015

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Cox BL, Carpenter AR, Ogle RA. Overlooking hazards in hazardous waste: lessons learned from case studies of hazardous waste/chemical reactivity incidents. American Institute of Chemical Engineers, 2014 Spring National Meeting, 48th Annual Loss Prevention Symposium, New Orleans, LA, March 30-April 3, 2014.

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Viz MJ, Ogle RA, Dee SJ, Cox BL. Hydrogen sulfide exposure from molten sulfur — A Forgotten Hazard? American Institute of Chemical Engineers, 2013 Spring National Meeting, 9th Global Congress on Process Safety, San Antonio, TX, April 28-May 2, 2013.

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Cox BL, Steen PH. Finite-amplitude dynamics of coupled cylindrical menisci. American Physical Society Division of Fluid Dynamics 61st Annual Meeting, San Antonio, TX, 2008.

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Appendix B

Testimony List

Brenton L. Cox, Ph.D., P.E., CFEI

March 2023

Brenton L. Cox, Ph.D., P.E., CFEI
Four Year Testimony List

April 18, 2022
Eric A. Bujak and Sondra Bujak v. Corrigan Oil Co., et al.
State of Michigan, In the Circuit Court for the County of Genesee
Case No. 18-110834-NO
Deposition Testimony

October 28, 2021
Giovannie H. Salazar v. Tate & Lyle Grain, Inc., et al.
United States District Court, Northern District of Indiana
Case No. 3:19-cv-103
Deposition Testimony

May 27, 2021
Cash-Darling v. Recycling Equipment, Inc.
United States District Court, Eastern District of Tennessee, Greenville Division
Case No. 2:19-cv-00034
Deposition Testimony

Appendix C

Computational Fluid Dynamics (CFD) Analysis

Computational Fluid Dynamics Analysis

A three-dimensional Computational Fluid Dynamics (CFD) model of the Didion Mill Facilities, which included the multi-story mill and warehouse structures, was developed using the FLACS-DustEx dust explosion solver. FLACS is a CFD analysis software program developed by Gexcon that is widely accepted within the process industry to provide numerical analysis for dispersion and explosion scenarios. The DustEx solver is part of the FLACS software package and was developed specifically to analyze the effects of dust explosions. The model accounts for the interactions between the deflagration, dust clouds, obstacles (e.g., milling equipment), and vent panels (e.g., frangible doors). DustEx can output dust explosion pressures, temperatures, and other parameter time-histories, which can then be used for other engineering analysis efforts (such as structural element evaluation).

In order to model the explosion in B1, it was necessary to establish a credible mass of fuel that could be ejected from the process in the time between the initial flames observed by Mr. Dodge and the explosion in B1. There were multiple opportunities for material to be released at ceiling level into B1, as described above in section 3. These included the upset and explosion within the SBM which had multiple inlets, the ruptured SBM Cyclone, and the SBM fan described in section 0. Also, the inlet to the NBM was severed, described in section 3.3.1.1. Another duct separated at the ceiling near the SBM and NBM that carried material to an airlock. However, the exact sequence of these separations cannot be established. For the purposes of this model, it will be assumed that material within the SBM and material held up due to the upset within SBM was ejected by one of the initial explosions.

The flow from the SBM is difficult to determine, as the process stream contains both product and unseparated fines material, and the fact that the material is recycled throughout the process. Additionally, no flow measurement devices were present in this system, and Didion employees reported that product flow rates were measured manually by diverting flow into a container for a set time period and then measuring that container. According to the mill PFDs, the design feed rate to the recycle loop containing the SBM was approximately 152 lbs/min (69 kg/min).[247] This material is destined for one of three locations: the SBM, to feed the nearby ethanol plant, and the Torit filter. The design recycle rate and production rate are not indicated on the PFD, and likely vary based on the incoming corn and other parameters. For example, on May 31, 2017, the NBM was also in service in the Bran System, which may have allowed for even higher throughput than the design values described above.

Depending on the yield and the fraction of material recycled from the SBM to the 4B Sifter, the feed could be either less than or greater than the feed to this subsystem (e.g., the design rate of 152 lbs/min). During the first shift on May 31, 2017, the production rate was 24 lbs/min (11 kg/min).[248] Thus, the average flow through the SBM over the same period was greater than 24 lbs/min (11 kg/min), since the yield is not 100%. The waste sent from the B-Mill to feed was at least 8 times greater during the same shift, which would correspond to a gross flow of 216

[247] REF-MILL-ENG-4202-01 Bran System S#2

[248] DIDION0001877

lbs/min if it were all to pass through the SBM, but this stream appears to be fed from multiple sources. Thus, the production data from the day of the incident are not explicitly helpful in calculating the flow through the SBM.

If the feed to the SBM were 152 lbs/min (69 kg/min), then a 30 second backup in the SBM due to a process upset would accumulate 76 lbs (34.5 kg) worth of material in and immediately upstream of the SBM. Only 65% of this material would need to be ejected from the SBM and/or its inlet ducts to suspend sufficient fuel to observe the damage, per Mr. Cholin's analysis.[249]

For the purposes of FLACS modeling, a nominal mass flow rate of approximately 110 lbs/min (50 kg/min) was assumed, about 72% of the design flow through this portion of the Bran System. A release time of 25 seconds would result in about 20 kg of fuel, approximately 10% less than the value adopted by Mr. Cholin. The dust was modeled as maize (K_{St} = 150 bar.m/s and P_{max} = 8.6 barg), and assumed to be present at a concentration of about 500 g/m^3, which was similar to Mr. Cholin's calculations.

Because the FLACS model is a CFD model, the fluid mechanics associated with the release must also be considered for the starting turbulence input conditions. A mass flow rate of 50 kg/min ejected through a 5" circular opening corresponds to a velocity of 132 m/s. The turbulence experienced inside the building was assumed to be 10% of the RMS turbulence. High speed flow inside complex geometries is typically between 5-20% so this value is justifiable inside a mill with extensive ducting, equipment, rooms, etc. The scale of the eddies in the room is assumed to be 1/10 of the diameter of the opening, resulting in a 0.5" (1.3 cm) eddy for the model to utilize as an input parameter.

To model the explosion, a 3D map of the Didion Milling facility was generated using the mill drawings, photographs, and drone footage. The minimum grid size used was 7.9 inches (20 cm). Figure 107 shows the DustEx CFD model results overlaid onto a 3D map of the Didion Milling facilities. The results are shown with a cross-sectional cut just below the second level of the B-Mill, which cuts partially through the Warehouse height. The DustEx model was structured to provide a reasonable approximation of the pressures from a single ignition source within the B-Mill at the site of the Bauermeisters Grinder on the B1 Level. The failure pressures of man doors and roll-up doors were specified in consultation with structural engineers, who describe the basis in their report.

[249] Cholin, John M. "Findings and Analysis Regarding the Explosion at Didion Milling, Cambria, Wisconsin May 31, 2017" Section 8.8.2. pp. 134-135, 181-182.

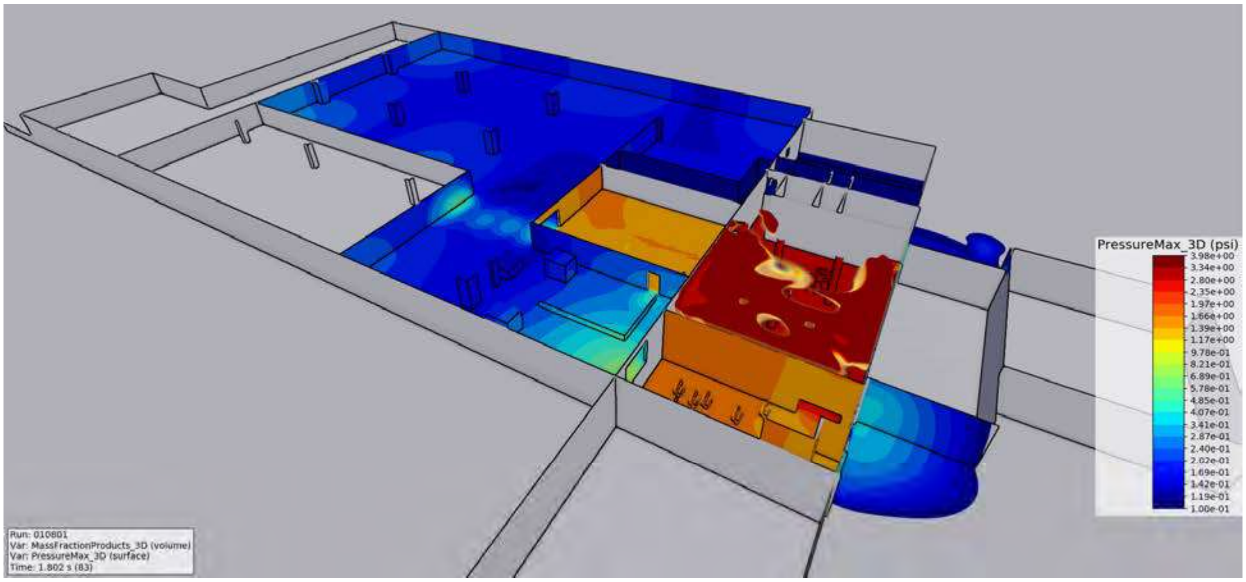

Figure 107. FLACS-DustEx CFD model results of the Didion Milling Facilities initiating on the 1st floor of the B-Mill. The results are only shown for the lower portion of the facility, even though the computational domain extends all the way to the top of the warehouse. The color contours indicate the maximum overpressures (in psi) experienced on surfaces. The deflagration extent at the end of the simulation (1.8 seconds after ignition) is shown in orange and red inside the 1st floor of the B-Mill.